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Governance, social and economic sustainability of WA's Western Rocklobster and finfish industries: An economic governance and supply chain analysis

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Abbreviations

For the Western Rocklobster Analysis

- ALB – Available Legal Biomass: the total estimated weight of a stock at the beginning of a fishing season.
- BB - Breeding Biomass: the total weight estimate of all mature female lobsters in a population.
- BSMA – Breeding Stock Management Area.
- CER – Catching sector economic returns
- CLB – Closing legal biomass: the total estimated weight of a stock at the end of a fishing season.
- DR – Decision rules: agreed responses that management would make under pre-defined circumstances regarding stock status and legal proportion harvested.
- HS - Harvest Strategy: the clear and specific articulation of how the system of management for a fishery will achieve its core sustainability, ecological, social and economic objectives.
- HSDR - Harvest Strategy and Decision Rules.
- IFM - Integrated Fisheries Management. It is the process used to divide the harvest of a fish resource between different stakeholder groups.
- ITQ - Individual Transferable Quota
- LPH - Legal Proportion Harvested: the proportion of legal lobsters harvested by the fishery each season: (LPH = Annual Commercial Catch / Estimated legal biomass1 available for capture over the season).
- MEY - Maximum Economic Yield: the catch level for a commercial fishery that maximises the PV of net economic returns based on prevailing economic conditions.
- MSY - Maximum Sustainable Yield: the maximum sustainable average annual catch that can be removed from a stock over an indefinite period under prevailing environmental conditions.
- NPV – Net Present Value
- P&M - Processing & Marketing sector
- PER - P&M sector Economic Returns
- PV – Present Value

- TAC - Total Allowable Catch
- TACC – Total Allowable Commercial Catch
- TARC - Total Allowable Recreational Catch
- TV – Threshold (floor) Value for egg production
- TV(CLB) - Threshold (floor) Value for CLB
- WRLF - Western Rocklobster Fishery.

Executive Summary

This study of fishery governance and regulatory systems was undertaken through the University of Western Australia by Principal Investigator, Associate Professor Paul McLeod, together with Co-Investigator, Dr Lindsay Joll of the WA Department of Fisheries. Dr Joll's principal role was to facilitate access to people, and data through his role as Director of Aquatic Management, Division of Aquatic Management at the WA Department of Fisheries. He also provided comment on various aspects of fisheries management covered in the report. Associate Professor McLeod coordinated the research, undertook the governance analysis, statistical analysis of prices and markets for lobster and finfish and the supply chain analysis of finfish. The research was assisted by Emeritus Professor Robert Lindner and Mr John Nicholls. Emeritus Professor Lindner developed and calibrated the detailed simulation model for rock lobster and undertook the supply chain analysis using the model. Mr John Nicholls worked on finfish data collection and on documenting the institutional management arrangements for finfish.

The focus was on the potential to improve financial viability of the supply chains for Western Rocklobster and the West Coast Demersal Scalefish Fishery. The project commenced in July 2011, and lasted three years. The study grew out of concerns that the potential value of research results with a long term focus on making fishers commercially viable have often not been fully realised. In particular, the absence of a coherent governance and management structure encompassing markets and marketing, pricing and product development, access to adequate stocks, harvest rules and funding of management and research is often cited as the reason for failure to benefit from the research.. In the study, supply chain models for Western Rocklobster and the West Coast Demersal Scalefish Fishery were developed and calibrated to investigate the impact of harvest rules and management regulations on economic returns to agents at all stages in the supply chain.

Background

In recent years, how fishers in several WA fisheries respond to significant changes in allowable harvests, including how they adjust their fishing behaviour, their business structures, and a range of other activities, have been investigated in a number of studies. Inter alia, such work has included surveys and analysis of the way that recreational and commercial fishers have adjusted to the changed circumstances in the WA Finfish fishery, especially the reductions in allowable catches. Other studies have involved detailed financial data collection and economic modelling relating to the economic performance of the commercial finfish sector in WA, and bio-economic modelling of the Western Rock Lobster industry to assess alternative management regimes. These and other studies have assembled detailed data, and produced detailed results, with implications for a range of economic and pricing issues across the finfish and lobster industries that are not necessarily well catered for in the governance structures currently implemented as part of Integrated Fisheries Management (IFM).

The genesis for this study was widespread recognition that while good quality data has been collected and analysed, much of this data has had limited impact. Moreover, in the absence of a coherent governance and management structure with a long term focus on making fishers commercially viable, the potential value of such research might be lost, or at least reduced. As a result, there is concern that many research projects funded to improve economic returns to fishers and/or other agents in the supply chain often fail to realise this aim. Consequently, the next major challenge is to develop a coherent governance structure within the longer term approach to IFM that can integrate the results from past and current research in a way that enables each element of the fishery to be financially sustainable.

Aims/objectives

The overall aims for the project were:

- Determine the optimal feasible strategies for sustaining industry profitability.
- Determine the optimal Governance structure to secure regulatory objectives at least cost
- Identify the relevant management information necessary to deliver sustainable commercial outcomes over time.

For the Western Rock Lobster case study, the focus was on identifying optimal parameters within the Harvest strategy and control rules for setting the TACC for this fishery. Complementing this analysis, the focus in the case study of the West Coast Demersal Scalefish Fishery was on investigating the feasibility

of alternative means of improving fishery returns by post-harvest governance interventions, such as generic advertising, relative to more efficient regulation of the catching sector.

Methodology

For the Western Rock Lobster fishery, the Harvest Strategy and Control Rules (HSCR) have two key objectives. A sustainability objective that sets a floor "threshold value" (TV) to egg production capacity is the primary overriding objective of the HSCR, with the aim of maintaining stock biomass at levels last experienced in the mid-1980s. A secondary TACC setting objective is to increase lobster abundance so as to reduce catching costs, and increase economic returns. It is envisaged that this will be achieved by fixing the TACC at a conservative level so as to limit the Legal Proportion Harvested (LPH) to some maximum proportion, and thereby build catch rates to a target level.

Based on historical biological data for Western Rocklobster from the Department of Fisheries, a “fit for purpose” biological model was developed as the core of a supply chain simulation model that integrated economic models of the catching, processing and marketing sectors. The model developed was used to simulate impacts of the various proposed harvest rules on biological sustainability of the fishery, as well as on volatility of harvest settings (annual TACC) and optimality of economic outcomes (NPV of net economic returns) for the catching, processing and marketing sectors, separately and combined.

For the West Coast Demersal Scalefish Fishery, a wide ranging review of pertinent literature was undertaken as a preliminary to establishing a broader framework of governance that could form the basis for an investigation of the supply chain. Absent the availability of detailed biological data for the West Coast Demersal Scalefish Fishery, a descriptive analysis of the supply chain was undertaken that reflects how each part of the chain is structured. Interviews with processors and retailers were used to estimate indicative margins for processing, wholesaling and retailing. Subsequently, a supply chain model was developed and calibrated to evaluate how harvest rules impact on agents in the supply chain, and whether there were broader governance matters that could be implemented beyond the harvest sector.

Results/key findings

For the Western Rock Lobster fishery, the maximum TACC in the long run for any given TV (CLB) was found to increase by a modest amount as the LPH parameter increased, but was relatively insensitive to the chosen floor for TV (CLB) for any LPH value. Stability of the TACC as measured by average TACC as a percentage of maximum TACC over the 46 year evaluation period was high, at about 80% for most HSCR settings, but less than 70% for TV (CLB) = 15,000t. This is a key issue with different implications for the processing and marketing sectors. Given fluctuations in recruitment and biomass, harvests will fluctuate if catching inputs are stable, and vice versa. For fluctuating catch levels, maintained processing capacity will need to be higher, and average processing capacity utilisation will be lower. In addition, variable catch levels may impact adversely upon average prices received if the processor has to market fluctuating output.

Somewhat surprisingly, net economic returns to the catching sector were found to be quite insensitive to the HSCR settings, or at least to the range of settings evaluated in this study. It seems that the HSCR settings influence profitability of the catching sector in complex ways that are largely offsetting. However, average returns hide the risk of significant downturns in annual returns that might bankrupt at least some firms. This study found that more conservative strategies involving TV = 15,000t, or more exploitative strategies involving LPH = 55%, run the greatest risk of a disastrous downturn in catching sector annual financial returns. On balance, the extremely small opportunity cost of choosing TV (CLB) = 10,000t and LPH = 45% rather than TV (CLB) = 5,000t and LPH = 45% more than justifies the much larger safety cushion in satisfying the sustainability objective by choosing TV (CLB) = 10,000t and LPH = 45%.

In contrast to the catching sector, net economic returns to the processing and marketing (P&M) sector are more sensitive to the range of HSCR settings evaluated. Estimated maximum NPV of net economic returns to the P&M sector of $481m was achieved by setting TV (CLB) = 5,000t and LPH = 55%. For the lower risk strategy of TV = 10,000t, the next best NPV estimate was $440m from setting LPH to 45%. Estimates of P&M sector NPV for the even lower risk strategy of TV = 15,000t were much smaller, and in the range from $324m to $366m. With regard to the worst financial year in the simulated time sequence of 46 years, it was estimated that the P&M sector would incur losses for almost all of the strategies, and is projected to sustain large and potentially fatal losses if the most conservative sustainability strategies were adopted.

The West Coast Demersal Scalefish Fishery is relatively small in value, with Snapper (Pagrus auratus) arguably the premier fish species for local consumers. There is competition for Snapper from other locally caught premium finfish such as West Australian Dhufish, Goldband Snapper and emperors. There is also competition from imported finfish, including imported Snapper.

Estimated mark-ups from applying known beach price and retail price data to the supply chain model were found to be consistent with findings reported in the literature and with what would be expected in a competitive post-harvest sector. The evidence also suggests that Snapper is already being delivered primarily to its highest value uses, namely as fillets and whole fish to local consumers. These findings, plus the demonstrable fact that the supply chain is contestable, suggest that super normal profits could not be sustained in the post-harvest supply chain for demersal scalefish in Western Australia. Hence, opportunities to increasing returns to fishers must rely on increasing the retail price for the particular demersal species caught, and/or by lowering the harvesting and management costs that are impacted by management rules.

Generic advertising has been suggested as a way of shifting demand and increasing price, but this would promote the cause of all fish producers by mainly shifting demand away from competing generic products, such as red meat and chicken. However, the availability of close substitutes from other domestic fisheries, and from imports, means that generic advertising is unlikely to be successful in raising prices for premium fish from the West Coast Demersal Scalefish Fishery. Moreover, commercial fishers are unlikely to receive higher market prices as compensation for catch reductions consequent on changes to harvest rules. Likewise, accurate labelling is unlikely to increase demand for catch from the West Coast Demersal Scalefish Fishery because retailers have adequate incentives to promote the accuracy of descriptions of Snapper given the premium price received.

Hence, management regimes that permit and encourage fishers to become more efficient offer the best opportunity to increase returns. For commercial demersal fishing, there is considerable scope to do so by rationalising the array of Management Plans, each of which applies to explicitly defined areas of the coastal waters, or even to sub-sets of those waters within the fishery. By contrast, fishing by the recreational sector (including charter operators) is managed within coastal waters falling within the defined Bioregional areas of ocean. Not only do the respective ocean boundaries for these competing resource user sectors not match, but also within each Management Plan, the primary management tool for commercial fishing is the allocated fixed number of fishing hours coupled with gear controls.

Since 2009, management of the demersal catch has been focused on reducing allocated fishing hours of commercial fishers, and reducing recreational bag and possession limits. In response to tighter input controls, commercial fishers have changed their fishing behaviour in ways that improve catch rates to preserve or increase net returns. As a result, since 2009, kilograms of fish caught for each hour fished has increased by almost 6% for the period to 2012.

Implications for relevant stakeholders

For the Western Rocklobster fishery, the integrated model developed highlights the importance of choosing the best parameter values for the harvest strategy and associated TACC setting control rules. The analysis also shows that given a stochastic PSI, adherence to these rules will necessitate large fluctuations in the annual TACC that are likely to cause difficulties for marketing in the major export markets. Before harvest rules are signed off, a risk analysis is needed that incorporates both biological and economic considerations. In particular, limiting the size of the adjustment to TACC in any one year to stabilise sales patterns can be made consistent with biological sustainability by maintaining relatively high levels of biomass.

For the West Coast Demersal Scalefish Fishery, the analysis suggest that improvements in harvest efficiency by reducing the complexity and cost of management plans are the logical place to look for improved fisher returns. This might include moving away from input controls based on time to some form of quota, although this would need prior assessment to ensure that critical issues such as the discard of over-quota species in circumstances where there are high levels of catching mortality, could be effectively managed. Redefining fishery management areas to have a species focus rather than a complex mix of geography and species and gear mix strategy as currently exists. Opportunities for government action further along the chain, including the use of generic advertising applied to local demersal species, have limited potential.

Recommendations

The ITQ management regime for the Western Rock Lobster industry has increased flexibility in matching production to the market between years, but the industry needs to optimize the pattern of catching and processing within any given year. Developing an intra-year model similar to that described here could help assess the implications on annual economic returns of shifting the monthly or weekly catch pattern.

For the West Coast Demersal Scalefish Fishery, a consideration of options to rationalise the array of management plans could be assisted by further research into the design and implementation of simplified management structures elsewhere and on the implementation and administration of quota based management tools in multi-species fisheries.

Keywords

Governance, supply chain, price mark-ups, bio-economic model, management plans, West Australian Rocklobster fishery, West Cost Demersal Scalefish Fishery, generic advertising, cointegration, legal proportion harvested, peurellus settlement index, Southern rock lobster (*Jasus* edwardsii), Western Rocklobster (*Panulirus Cygnus*), tropical rock lobster(*Panulirus* spp except *P. Cygnus*)   Snapper (*Pagrus auratus*)   Goldband Snapper (*Pristipomoides multidens*), red emperor (*Lutjanus sebae*), Saddletail Snapper (*Lutjanus malabaricus*)

Introduction

In recent years, substantial changes have occurred in Western Rocklobster and West Coast Demersal Scalefish Fishery.

In respect of the Western Rocklobster Fishery, a decline in biomass meant that annual catch tonnages had to be contracted substantially. This coincided with the move to ITQ's as the management system. Given that the fishery needed to be managed with a lower harvest, a major concern to fishers and processors was how the lower harvest and the rules for catching it would affect fishery returns, both currently and into the future. In particular, how harvest rules interact with processing and marketing decisions to influence returns to fishers and processors is a particular concern.

The West Coast Demersal Scalefish Fishery also has been subject to similarly drastic degree of harvest contraction, albeit for somewhat different reasons. Finfish stocks, as reflected by indicator species, Snapper, Baldchin Groper and West Australian Dhufish, have been assessed as being overharvested. Since 2009, fisheries managers have introduced a range of measures to reduce effort and catch. Again, the way that these changes affect the returns to fishers is a major concern. As with rock Western Rocklobster, the effect of these charges in harvest on returns to fishers depends on the economic relationships along the supply chain.

How fishers respond to significant changes in allowable harvests, including how they adjust their fishing behaviour, their business structures, and a range of other activities, have been investigated for several WA fisheries in a number of recent studies. Inter alia, such work has included surveys and analysis of the way that recreational and commercial fishers have adjusted to the changed circumstances in the WA Finfish fishery, especially the reductions in allowable catches. Other studies have involved detailed financial data collection and economic modelling relating to the economic performance of the commercial finfish sector in WA, and bio-economic modelling of the Western Rock Lobster industry to assess alternative management regimes. These and other studies have assembled detailed data, and produced detailed results, with implications for a range of economic and pricing issues across the finfish and lobster industries that are not necessarily well catered for in the governance structures currently implemented as part of Integrated Fisheries Management (IFM).

The genesis for this study was widespread recognition that while good quality data has been collected and analysed, much of this data has had limited impact. Moreover, in the absence of a coherent governance and management structure with a long term focus on making fishers commercially viable, the potential value of such research might be lost, or at least reduced. As a result, there is concern that many research projects funded to improve economic returns to fishers and/or other agents in the supply chain often fail to realise this aim. Consequently, the next major challenge is to develop a coherent governance structure within the longer term approach to IFM that can integrate the results from past and current research in a way that enables each element of the fishery to be financially sustainable.

Historically, the sole focus of fisheries governance was on biological sustainability of the fishery, and the primary objective of the Department of Fisheries was to ensure that stocks were maintained to allow maximum sustainable yield (MSY). This interpretation of governance was assumed to ensure the best possible societal outcomes from harvesting fish.

More recently, the governance concept has been extended with the adoption of integrated fisheries management (IFM) and ecologically based fisheries management (EBFM). The objective of IFM is manage catch levels to maximise overall economic returns to the community at large, and to share/allocate the available fish harvest between the competing users in the most efficient manner possible. Under EBFM, specific reference is made to the role of the fish stock within the wider ecology of the region. Even with these extensions, the governance focus has still been on sustainable yield, although the estimate of sustainable yield is influenced by EBFM considerations, and how that yield is to be shared is influenced by IFM considerations.

Concurrently, policy makers have come to recognize that maximum economic yield (MEY) was theoretically superior to maximum sustainable yield as a goal for managing fish stocks. Put simply, in a static model with given beach prices, reducing catch would have the effect of increasing stock biomass, and hence improving catchability, lowering catch costs and increasing net returns. Increasing numbers of fisheries managers are now looking to MEY as a management objective[1], but it focusses only on the catching sector, and does not consider returns to other sectors in the supply chain.

Traditionally, organisation of the supply chain beyond harvesting, comprising primarily processors, wholesalers and retailers, has not been of great interest to fisheries managers. By contrast, the behaviour of the catching sector has a direct bearing on the effectiveness of policies to control catch. Hence, fisheries managers have significant direct interaction with fishers in the design and implementation of harvest control policies. Even here however, the broader economics of the sector, especially prices received by fishers, have not been of direct interest to fisheries managers. Along the supply chain, the behaviour of retailers, processors and wholesalers has a potentially significant role to play in influencing the ultimate return to fishers.

Arguably, there is a need to review and rationalize fishery management by focusing on the whole supply chain. In particular, enhanced value to fishers is conditional on;

- Harvest rules. Long term financial and economic sustainability of the catching processing and marketing sectors is potentially enhanced by having harvest rules and resource sharing rules that give a degree of certainty in terms of either rules or volumes. Such rules will be more consistent with achieving improved marketing outcomes. They will also be more conducive to rationalization to achieve economic scale.
- Funding and governance. The organisation of the industry including the way it funds management, delivers R&D and marketing will influence how efficiently it delivers outcomes to fishers and works its way through periods of major transition.
- The impact of fish availability, and quality on price in key international (lobster) and domestic (finfish) markets. An understanding of the drivers of price formation – and the role of close substitutes in setting beach, wholesale and final market prices will be essential to understanding how value to fishers can be enhanced and how harvest strategies potentially affect economic and financial returns.

A logical way to investigate this phenomenon in a consistent way is to look at value created along the supply chain, and the interaction between the supply chain outcomes and harvest strategies, which are the current core focus of fisheries management for the Western Rocklobster and the West Coast Demersal Scalefish Fishery.

Supply chain analysis is a relatively recent development. It is premised on first understanding linkages between sectors in the chain, and then seeking to determine whether the operation of the chain is yielding the optimal outcomes in terms of returns the fishery. From an economic perspective, direct government involvement in the supply chain would be based on a market failure argument, such as a lack of competition, or under-provision of public goods. This

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[1] In Australia fisheries managed by the Commonwealth have lead the way in this regard.

could occur at three levels. First, competition failure may mean that monopsony buying power is exerted against fishers[2]. Second, high transactions costs, especially set up costs, may mean that fish products are not optimally marketed. Truth in labelling and quality control are subsets of this. Third, the public good aspects of R&D may mean that insufficient R&D is undertaken on new product and market development.

This project has at its core the link between management of a fishery to achieve biological sustainability, and realisation of economic outcomes within the supply chain. Hence, a supply chain analysis is a logical framework to investigate these issues. For this study, a supply chain model was applied to both the Western Rocklobster and West Coast Demersal Scalefish Fishery.

Along the supply chain, the link from biological sustainability to economic performance works through the relationship between (i) catching costs and harvest levels, (ii) processing costs and harvest levels, and (iii) market price and harvest levels. Management decisions taken with respect to biological sustainability and allowable harvest will impact upon economic performance through these particular relationships. Moreover, there may be further decisions that could be taken that would enhance economic performance and allow for the consequence of the harvest decisions to be ameliorated. An example might be product marketing that has the effect of securing higher product prices that can in part offset the consequences of harvest reductions. The project looks at these further issues where relevant.

It is important to recognize that, noting the points made previously about the need to justify intervention with evidence of market failure, there may or may not be a legitimate role for government beyond management of harvests. This will depend on the exact nature of the interrelationships and specific outcomes along the chain.

[2] Much of the initial work on supply chain and value chain analysis was done through the FAO with a focus on developing country fisheries reflecting precisely this concern. On the other hand, the focus on supply chains in European fisheries has primarily been about understanding the economic linkages and determining whether value can be enhanced through strategies like sustainability certification, truth in labelling and fish promotion.

Objectives

The following were the project objectives.

1 Determine the optimal feasible strategies for sustaining industry profitability

2 Determine the optimal Governance structure to secure regulatory objectives at least cost

3 Identify the relevant management information necessary to deliver sustainable commercial outcomes over time

Method

A review of the literature indicated that a supply chain model was the most appropriate way to represent the relationship between governance, biological and economic outcomes.

For each fishery, a supply chain structure was identified that linked harvest through to final consumer. The supply chain specified for each fishery was based on the literature review, previous studies of the fishery and interviews with fishers, processors and distributors and retailers.

The analysis of the supply chain varied between the two fisheries based on inherent differences in their structure and management and the availability of data.

The Western Rock Lobster fishery is primarily an export fishery and has a dominant processor/marketer exporting principally to China and Hong Kong (SAR). The fishery is managed at the harvest level through ITQs and a set of Harvest Strategy and Control Rules (HSCR). These rules have two key objectives. The sustainability objective sets a floor "threshold value" (TV) for egg production capacity. This is the overriding objective of the HSCR, with the aim of maintaining stock biomass at levels last experienced in the mid-1980s. A secondary TACC setting objective is to increase lobster abundance to reduce catching costs, and increase economic returns. It is envisaged that this will be achieved by fixing the TACC at a conservative level in order to limit the Legal Proportion Harvested (LPH) to some maximum proportion, and thereby build catch rates to a target level.

Based on historical biological data for Western Rocklobster from the Department of Fisheries, a “fit for purpose” biological model was developed as the core of a supply chain simulation model that integrated economic models of the catching, processing and marketing sectors. Monthly data on export prices was obtained from the ABS back to 2000 as the basis for setting demand parameters in the model. Previous studies on fishing and processing costs and interviews with fishers were the basis for determining the mix of fixed and variable processing and harvesting costs used in the model.

The model developed was used to simulate impacts of the various proposed harvest rules on biological sustainability of the fishery, as well as on volatility of harvest settings (annual TACC) and optimality of economic outcomes (NPV of net economic returns) for the catching, processing and marketing sectors, separately and combined. Feedback on marketing and demand from the major processor was used as the basis for determining an appropriated specification to test the sensitivity of the results to varying demand parameters.

The West Coast Demersal Scalefish Fishery harvest is sold locally through a range of retail outlets. There are a number of processors and distributors. Although there are a number of licences, harvest of major species is dominated by a small number of fishers. Public domain data is limited on pricing and costs. There is no detailed biological data and model such as exist for Western Rocklobster that can be used as the core of a supply chain model.

A wide ranging review of pertinent literature was undertaken as a preliminary to establishing a broader framework of governance that could form the basis for an investigation of the finfish supply chain. Absent the availability of detailed biological data for the West Coast Demersal Scalefish Fishery, a price mark-up model was developed. This model documents each link in the supply chain and uses a mark-up to translate each price back to the next price in the chain. Essentially a descriptive analysis of the supply chain reflecting how each part of the chain is structured, it allows the retail price to the final consumer to be translated back to the wholesale price, the processor price and ultimately the price paid to the fisher through the application of the appropriate price mark-ups. Interviews with processors and retailers were used to estimate indicative margins for processing, wholesaling and retailing. The supply chain model was calibrated based on estimating the processing, wholesaling and retailing margins that reconciled that catch price data at one end of the chain and the retail price data at the other. These indicative margins were cross-checked with the available data on margins from similar studies overseas and in Australia.

Indicative retail prices were obtained from price lists of major retailers. Analysis local and import prices allowed an assessment of the competiveness of the market and the role of local and imported substitutes in setting prices for the main species of interest, namely Snapper and West Australian Dhufish. A time series of catch price data was obtained directly from fishers who provided individual trip catch and price data for a two year period.

The West Coast Demersal Scalefish Fishery is managed at harvest level through a combination of effort controls. The primary control is limits based on fishing time. A review of the actual and potential management policies was undertaken to evaluate how harvest rules impact on agents in the supply chain, and whether there were broader governance matters that could be implemented beyond the harvest sector to improve returns to fishers.

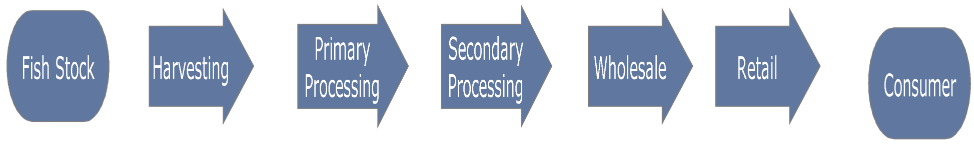
Generic advertising of local finfish is one option suggested as a way of securing higher returns. This requires that generic advertising of the nominated fish species would shift the demand curve sufficiently to the right to generate a price increase. A simple demand and supply model is constructed that allows the impact of generic advertising to be assessed and the conditions under which it would increase the price received by fishers to be determined. The potential to use this strategy to increase returns is then is then assessed based on the likely demand and supply parameters applicable to the species in the West Coast Demersal Scalefish Fishery.

Results

Supply Chains and Value Chains

A distinction is made in the literature between supply chains and value chains. The exact configuration of the supply chain will vary from fishery to fishery but the most general representation is that shown in Figure 1.

Figure 1: Basic Supply Chain



Particular fisheries may have more or fewer links in the chain and more or fewer participants at each stage in the chain. Multiple links may occur if parts of the chain divide to produce different product (e.g. live versus processed fish) or service different markets (e.g. live versus frozen, supermarket versus restaurant, domestic versus export)

Along the chain, participants are most obviously connected by private commercial transactions. These interactions may be in the form of detailed commercial contracts over extended periods or simple market trading at spot prices.

Individual players in the chain may participate at one part of the chain or at several places in the chain via vertical integration. The extent of any vertical integration will reflect the actual and perceived relative efficiency of having transactions organized through external commercial transactions or through internal administrative transactions.

Governance of a fishery embraces the transactions and interactions between players at one level within a chain and between players across the stages in a chain.

Along the chain, there is a range of activities required to bring a product from raw material through intermediate production to the consumer (Kaplinsky, 2000). A typical seafood value chain consists of harvesting (fishing or aquaculture, or a combination of both), primary processing, secondary processing, distribution and marketing and finally consumption.

Value to the final consumer is created along the chain as each of the firms seeks to add value by combining capital and labour through an optimized production process. Each step adds value to the previous step. This may be measured as the margin or difference between the selling price from a segment in the chain and the cost of inputs into that segment.

Different segments will have different margins and a greater or lesser share of the value added throughout the chain. How value is distributed along the chain will be affected by the bargaining power of players at each stage. This is turn will be influenced by the number and relative size of players each stage. It will also be influenced by the nature of competition in the final market place and the extent of product differentiation. The latter will determine the extent to which the product is in a price-taking environment or is able to command a premium.[3]

[3] Differentiation in the lobster market is typically connected to measurable attributes like size and texture. In the export market the Southern Rock commands a premium connected to size, texture and in part robustness.

Each step in the value chain can be analysed in terms of the relevant price and cost items and the resulting profit margin. This allows for calculation of the relative weight of each segment in the overall consumer value.

The schematic shown above does not specifically reference transportation. It is typically included in wholesale/distribution. However, transportation is a critical link between segments. For example, initial processing of a catch may occur at the port of landing with the product transported to a major city for further processing. Wholesale operators may then distribute the product to domestic markets or overseas. Once overseas a further layer of wholesale/distribution may occur before the product is passed to retail and other final consumers. For the live lobster market, airfreight direct to the market is a critical component of the chain because wholesalers expect to distribute live product to customers within days.[45] In fact, in some cases wholesalers distribute lobster direct to customers from the airport thereby saving the costs associated with keeping the lobster in tanks at their own premises.

Components of the supply chain

Number of segments - Degree of Vertical Integration

The structure of any particular supply chain will reflect the nature of the required transactions and the efficiency of organizing transactions externally or internally.

Much has been written about the boundaries of the firm and vertical integration. With regard to the lobster supply chain, the relevance of this work is that governance arrangements can affect the efficiency of alternative vertical arrangements. Particular issues relevant to the Western Rocklobster supply chain are (i) the extent to which domestic producers could benefit from direct participation in the marketing of Western Rocklobster products in overseas markets and (ii) the extent to which it would be beneficial for processors to integrate into the catching sector by owning quota.[6]

The degree of vertical integration in any chain is fundamentally determined by the nature of the transaction costs associated with establishing and managing contracts. This idea stems from Coase (1937). In essence, it says that a firm or industry will integrate across distinct production processes so long as doing the work in-house is cheaper than purchasing the input or service in the market. [7]

The basic behaviour of the various participants in the chain will have a bearing on the structure of the chain. For example if each stage in the chain was characterized by perfect competition, then each stage in the chain would have least cost production and all market transactions would take place at prices equal to marginal cost. This would reduce the incentive to integrate.

For a variety of reasons, the assumption of perfect competition may not be valid. In fisheries, even when there are a large number of small catchers harvest rules will influence their behaviour. For example under an ITQ, the total catch is restricted to the TACC and individual decisions may only be competitive in respect of the optimal time for a fisher to catch their

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[4] Delays in air freight pose risks of increased mortality and losses to the wholesaler. For example, Western Rocklobster can be flow direct from Perth to Hong Kong. South African lobster will experience a 30 hour flight with a stop in Malaysia or Singapore. Any delays in these ports substantially increases risk of loss.

[5] Some lobster can be kept fresh in tanks for two to three weeks but this reduces turnover for the wholesaler.

[6] For example, this may be by participation at trade fairs, direct marketing to food chains in overseas markets or by providing marketing assistance to overseas wholesalers/distributors to better market the product.

[7] This is especially relevant to the rock lobster industry because the move to ITQs and changes to the harvesting regime mean that incentives may be crated for processors to own and operate quota.

allocated quota. Where this is the case, the relationship between catchers and processors combined with behavioural uncertainty may provide an incentive to integrate vertically. Information asymmetry and the difficulty of managing contracts may also provide an incentive. In the case of Western Rocklobster, contracts need to be established that get fishers to deliver catch within the ITQ with an appropriate monthly and perhaps even daily pattern. This can be done by the processor establishing price signals to elicit the appropriate catching response or by a more integrated route with the processor taking a direct interest in catching via owning some quota and contracting for the catch behaviour they wish to receive.[8]

Insofar as behaviour is concerned, Williamson (1985) identified opportunism in commercial relationships as source of uncertainty. The consequence of opportunism is that participants in commercial relationships need to screen those they enter into relationships with before they do so. They then must create a set of appropriate safeguards to limit possible actual undesirable outcomes. The degree of difficulty in achieving a desired arrangement will in part depend on the extent to which players are governed by bounded rationality or pure opportunism. Understanding this dynamic is critical to assessing the overall performance of the chain. A good example is the purchasing decisions by Great Hall in Hong Kong. They specify the water quality for holding live lobster and other fish and then need to ensure that anyone who participates in their supply chain commits to this water quality. [9]

Once we admit the possibility that players may be governed by a range of incentives, we need to recognize the inherent principal agent problem that is created in the supply chain. With incomplete information and uncertainty being a characteristic of most business relationships along a supply chain, both adverse selection and moral hazard problems potentially arise. Adverse selection arises when the principal cannot ascertain if the agent accurately represents their ability to deliver the product outcomes for which a contract is being offered. For example, a buyer may face the problem of determining if a live lobster wholesaler can actually deliver the water quality required and for which they are contracted. Moral hazard arises when the principal cannot be sure if the agent will put in their best efforts in working within the contract. In the previous example, this would arise if the wholesaler were tempted to substitute less good and cheaper water for the required water quality even though they have the capacity to deliver the higher water quality.[10]

Porter (1980) highlighted the potential to gain a competitive advantage through vertical integration. The competitive advantage in this case arises when there is imperfect competition. The firm can generate an advantage through operational economies based on combining operations across the chain, from better managing information flows between segments in the chain, from implementing better internal control procedures across the segments in the chain and from structuring incentives to align better with overall goals. Largely, the impact of these changes is the reduction of uncertainty. This reduction of uncertainty is used by Pfeffer and Salancik (1978) as an argument for vertical integration.[11]

It might apply to the catching and harvesting sector for Western Rocklobster if, for example, the incentives for fishers could be better aligned to those of processors by direct internal control as opposed to market based incentives and signals.

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[8] If the fisher is required to deliver particular qualities of catch then this may be more efficiently achieved with direct management as opposed to arm's length incentives built into contracts or offered as price signals.

[9] For live lobster, many wholesalers are thought by Great Hall to have inferior water quality and so Great Hall does not source from these firms. Pers comm. Tim Broderick, executive chef.

[10] The effect is to push up the transaction costs for those firms requiring the higher water quality because they have to engage in monitoring. In Hong Kong, Great Hall does not source from the Aberdeen Fish Market for this reason. It manages water quality by having a more direct say in the supply chain.

[11] Transaction cost economics provides a similar rationale as outlined below.

An important consideration is whether the improvement sought by direct control is about reducing costs, or quality control. Increasingly, ensuring quality and safety along the agricultural supply chain is seen as critical to long term market success. Taking greater control of the supply chain and the implementation of market transactions with appropriate incentives are seen as alternative ways to achieve this end. [12]

Transaction cost economics and the structure of the supply chain

While information asymmetries, uncertainty and associated adverse selection and moral hazard arguments may justify vertical integration, frequently a simple consideration of transaction costs can also inform the way that linkages across layers in the supply chain develop.

Transaction cost analysis has been used extensively to investigate vertical coordination in agriculture where the key issues relate to the relationship between growers and processors.[13]

The transaction cost structure ultimately influences the optimal governance arrangement because it influences the optimal degree of vertical integration to achieve a specified market goal.[14]

Williamson (1985) identified asset specificity, uncertainty, and frequency of transactions and transaction characteristics as key factors affecting the relationship between agents in the chain.

Asset specificity represents the degree to which an investment is specialized to a particular supplier or buyer. To the extent that it is, then substantial switching costs might arise. Indeed a substantial portion of these costs may be sunk costs if either party moves away from the arrangement. Ensuring a stable throughput of product may be critical for someone who has specific assets committed to a process. For example processing live lobster is relatively straight forward as it is based on relatively simple technology. This allows a processor to handle catch variation relatively easily. However, a processor heavily committed to more complex processing will have more advanced equipment and may not be easily able to handle catch volume variations or to switch between species. Ensuring a stable ongoing supply of product to process then becomes more critical. This same argument applies to importers/wholesalers. For live rock lobster, the key production parameters are water temperature, salt concentration and water volume. Wholesalers/importers can adjust these things relatively quickly, within a few hours. Hence, if once species of lobster is unavailable, such a Southern Rock, they can switch relatively easily to handling another such as Western Rocklobster, or Mexican Tropical Rocklobster or South African Rocklobster. This limits the scope for opportunistic behaviour by processors but increases the potential for opportunistic behaviour by wholesales/importers.

Uncertainty also arises because of unanticipated environmental changes or from unanticipated behavioural responses by agents in the chain.

Broadly speaking where fishing is involved we can identify two types of environmental uncertainty. First, there is the inherent environmental uncertainty that reflects the stochastic nature of the biomass. This is important in the Western Rocklobster industry affecting both intra and inter year harvest outcomes. Recently a reduction in catches and biomass signalled that traditional stable high catch levels appeared suddenly not sustainable and management

[12] For example in Australia, Coles has a stated objective of shifting to free range eggs in its stores. It can pursue this by more direct influence up the supply chain or by offering price incentives to deliver more free range eggs.

[13] Frank and Henderson, 1992; Hobbs, 2000; Hobbs and Young, 2001.

[14] At this point, we can see transaction costs as influencing the relationship between private players in the market, for example lobster fishers and processors. Ultimately, however, other transaction costs will influence the optimal way for the management regimes to be developed and administered by Government. This is considered below.

plans had to be adjusted to reduce catches from their long term average of around 11, 000 tonnes to around 5,000 tonnes.[15] Second, there is also the more recognized uncertainty inherent in the broader market environment. Fundamentally, this is demand (price) uncertainty but there may also be a quality uncertainty when harvesting fish. [16]

Frequency refers to how regularly transactions are conducted. Greater frequency of transactions provides faster feedback and offer more frequent opportunities to “adjust”.

In all agricultural supply chains, ensuring quality along the chain is a critical factor. Frequently quality attributes are hard to measure. For example, species, size and texture of Western Rocklobster meat may be directly observed. However, water quality and even length of duration in tanks may not. In the case where quality attributes are difficult to measure, agents may adopt opportunistic behaviour, exploiting their private information by failing to perform as agreed. Logically for agents committed to the chain long term, such as major processors, wholesalers and buyers this will likely lead to contracts with specific features to mitigate the risk or moral hazard. (Martinez, 2002). A key question is whether achieving the desired outcome is best approached using contracts in vertically integrated systems or through contracts managed as independent market transactions.

Lawrence et al. (1997) has argued that in agriculture, long term contracts allow transaction cost savings compared to traditional marketing channels. Farmers may also save transaction costs through long term contracts, e.g. by settling a premium for higher quality with a one-time negotiation. This may well be true for processed products in fisheries but as is argued below, substitutability is so strong in the case of live lobster this is unlikely to be the case.[17]

The pursuit of quality for the final consumer is expected to influence the optimal supply chain strategy. Raynaud et al. (2005) has argued that the governance structure choice is a function of the strategy being pursued by the firm for guaranteeing quality.

Value chain

In the management literature, a distinction is made between the supply and value chain. Porter (1980 and 1985) encapsulates the differences. Porter (1980) defined vertical integration as the combination of technologically distinct production, distribution, selling and/or other economic processes within the confines of a single firm. The justification for the integration resides in transaction cost efficiencies and overcoming uncertainty related to adverse selection and moral hazard.

Value chain analysis is slightly different. Porter (1985) divides value activities into two broad groups, primary activities and support activities.

Primary activities include creating the product, marketing the product, delivering the product to buyers, as well as delivering after-sales assistance/service. To deliver the primary activities successfully most products require inbound logistics, production operations, outbound logistics, and marketing and sales and service. Translated into a lobster market, inbound logistics would include receiving and storing lobster. Operations would include, preparing and packing for live export. Outbound logistics includes organizing airfreight to locations where buyers (wholesalers/distributors) operate. Marketing and sales includes all activities that facilitate purchase of lobster. It can encompass advertising, pricing, price information,

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[15] Aquaculture faces similar risks related to storm events and disease events.

[16] Recent literature has increasingly focussed on the nature of the price information in the seafood chain and the impact that this information has on supply decisions. See for example Jaffry (2005).

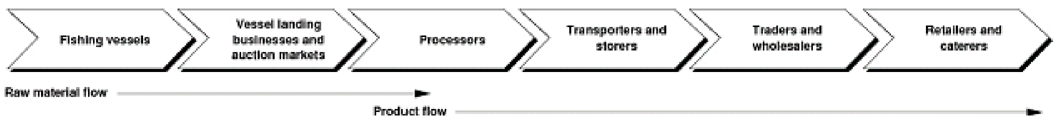
[17] The benefit of long term contracts with quality premiums is likely to be more significant in the case of aquiculture where the product is being sold to a tightly regulated supermarket supply chain.

promotion, channel selection, channel relation and pricing. Service would typically include anything that enhances the value of the fish product after it is sold and delivered, such as training chefs in preparation of the product or final consumers in the same thing.[18]

Support activities underpin the primary activities and each other by exchanging inputs. Support activities are classified into four categories, namely procurement, technology development, human resource management and firm infrastructure.

A typical fish distribution chain is shown in Figure 2.

Figure 2: Simple fish distribution chain



Source: Jensen (2009)

The idea of a value chain moves beyond this as a set of technical linkages to focus on how value is generated and enhanced. At each stage, this requires an understanding or price determination for inputs and output. The balance between these is reflected in the margins ate each stage. In pursuing the value chain as an analytical approach models need to capture as much complexity as necessary to understand the underlying value relationships but no be so detailed as to be purely a description of the interactions along the chain.

The way that value chain activities are organized and pursued determines costs and margins.

The way that firms can influence these outcomes will depend on how the demand and supply conditions at each point in the chain operate. This is considered further below as a precursor to developing a model for Western Rocklobster.

Governance in supply and value chains

The operation of supply chains and value chains can be described in a very descriptive way – materials movements, key decision points, approvals etc. This has a role to play in understanding how and where value is created. For example, an analysis of demand and supply conditions at each stage will allow an assessment of margins along the chain, and the way that the overall surplus is distributed.

Alternatively, the exact relationships between market agents (producers, processors, marketers, customers) and between market agents and government can be conceptualized as a governance structure. This is a particularly useful way to think of the value and supply chain for fisheries where there is an overt role for Government in implementing a biological management regime and even in promoting the product.[19]

When an industry has a mix of governance arrangements, the interaction between them becomes an important determinant of overall performance. The governance structure embedded in the private contractual arrangements to influence relationships between agents

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[18] For example, in promoting eggs AECL provides recipes, encourages leading chefs to use its egg products in developing recipes and in promoting recipes to consumers.

[19] Government's role in promoting agricultural products is long established in product areas such as meat and eggs, both in Australia and overseas. See Linder and McLeod (2012) for a recent analysis of generic advertising of eggs. See also Brester, G. W. and Schroeder, T. C. (1995) Kaiser (1998) and Capps, O. Williams, G. J. and Dang, T. (2010) for an analysis of generic advertising and meat demand. Promoting health via heart tick awards appears to have a positive impact on demand. See Lindner and McLeod (2012). A policy of generic advertising for lobster has been suggested by Callendar (2009)

and implemented by the government to influence the behaviour of agents, need to work effectively both as independent elements and in conjunction. Together they must create the environment in which transactions can be repeated on a consistent basis. In a fishery, the relationship between the catching sector and the processing sector is an example. The processing sector requires a reliable and consistent supply tuned to the needs of its buyers. By having such supply predictability, it can make more efficient investment decisions about processing capacity and develop more consistent long term marketing strategies. The catching sector similarly can optimize its investments and the wholesalers/marketers can embed this into marketing. While a processor may be able to influence this outcome by a mix of price signals, contracts and even vertical integration into catching, the overall harvest needs to satisfy the sustainability requirements set for the fishery.

The Western Rocklobster fishery provides a good example of these interactions. The previous management regime meant that the industry was input controlled and had a limited season. This meant that on an annual basis, live product could not be supplied for about half the year. Catches varied significantly between years and within the season, significantly between months. In the live trade, this translated into some price instability. The government needed to set controls (season and inputs) to balance the annual aggregate catch to the biomass. One effect has been that other lobster species supplied consistently year round to markets in Hong Kong and China, have gained some competitive advantage. Maine Lobster falls into this category. Its consistent supply and price has meant that buyers can plan well in advance to have the product on future menus with some price predictability.[20]

The proposed move to ITQs and year round catching changes the market circumstances for Western Rocklobster. The government will need to set TACC consistent with biomass targets but the ability of fishers and processors to plan for stable catches is enhanced. A corollary for buyers may be prices that are more predictable. This will allow buyers potentially to access other markets where supply and price stability are key.

Internal (market) Governance

The private arrangements between firms along the chain can be thought of the as the internal governance. How this plays out is crucial to long term success. For example, large retail buyers may set product quality and delivery standards and these then condition linkages back up the supply chain to the producer. Contractual and relationship arrangements will be developed to ensure that the buyers' requirements are met. Incentives will be set accordingly. In lobster, an example might be specifying a size/weight range preferred by the buyer. It might be specifying the temperature range in holding tanks. Along the chain, individual players will then adapt their own operations to ensure that they can meet requirements optimally, that is at least cost.

The internal governance arrangements must be able to cope with dynamic adjustment. Changes to the structure at any level must be fed optimally along the chain. For example, a supermarket may decide to focus on home brand eggs or to stock only free range eggs. These decisions change the relationship it has with producers and distributors.

The internal arrangements are essentially market transactions. Largely, they will reflect the particular technologies available and the efficiency of alternatives arrangements between agents. An indicative arrangement is shown in Figure 3. It shows four different stages for a seafood chain. The first diagram is the market for the raw material (e.g. finfish or lobster). The demand is the demand from processors and shows how they respond to price. The supply is the response of the catching sector to price. The market or equilibrium price is the beach

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20 For example some wedding function firms need to book and plan menus a year out from the event.

price for finfish or lobster. It determines revenue to the fisher and is an input cost for the processor.

The supply function is shown in conventional form with a positive slope. It will in part be a function of fisher behaviour and in part, a function of the way the catching sector is managed via external governance. An unregulated catch may result in the classical backward bending supply curve. A regulated catch with a constant TACC may generate a vertical supply at quantity caught equal to the TACC.

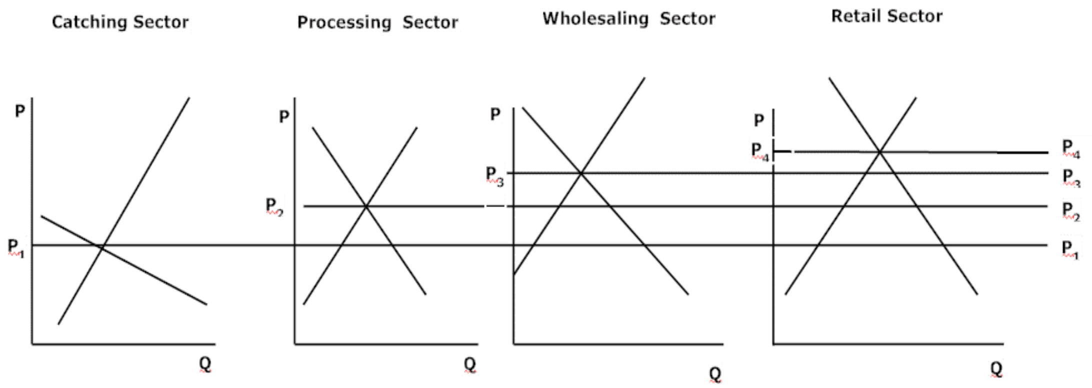
The equilibrium price P_1 becomes the minimum price at which the processor can sell his product to the next market level. The processor typically adds value by curing, freezing, filleting or supplying chilled or live fish. For each activity, an optimal combination of capital and labour must be determined.

At next level, the wholesaler is the customer or buyer of the processor. The wholesaler adds value through their distribution chain and their marketing skills or both. They may store fish products for long periods (e.g. frozen food) and manage demand by supplying from inventory. In the case of live fish such as live lobster, they will hold for very short periods (from a few hours to two or three weeks) with their focus on shifting the live product quickly to restaurants and hotels. Either way, the wholesaler acts as a buffer for the market. The processor price is an input cost to the wholesaler.

After the wholesaler, the number of markets will vary according to the exact product. A general case might have a retailer/restaurant at the final stage. The demand for the services of the wholesaler is generated by the retailer. The retailer/restaurant demand is generated from final customers. They add value by the way they display/market/prepare fish for sale.

Price is marked along the chain from p1 to p4. Put simply each step generates margins. In these are (p2-p1), (p3-p2) and (p4-p3). How the price is determined and the nature of the mark-ups will reflect the underlying demand and supply conditions at each stage. For example, if there are many substitutes then the demand curve will be relatively flat. If for example, lobster species (e.g. Western, Mexican, and South African) were thought to be close substitutes and if these were thought to be close substitutes for say Maine Lobster, then demand curve for any one species would be price elastic. This would imply a limited ability to have a substantially higher price mark-up for any one species.

Figure 3: Demand and Supply along the Supply Chain



External Governance

External governance of the supply chain is essentially about government and involves a mix of legislation, executive decision making and compliance. Legislation creates the legal environment within which the chain functions. Executive decisions create the implementation system and the strategies required to give effect to the legislation, including monitoring. The compliance regime enforces the sanctions defined for breaches of the legislative and implementation requirements.

For a fishery, the legislative framework will determine the rules for participation in the fishery including; licensing, gear requirements, education and training standards, quota ownership etc. It will specify conformity with local quota and harvest rules. In the case of Western Rocklobster, the legislation framework includes the requirement to hold a licence and to own or have the right to catch quota. A particular focus of external governance in fisheries has been to achieve biological sustainability often based on using input or output controls to secure harvest at the maximum sustainable yield.

A particular aspect of external governance that is prevalent in agricultural supply chains is marketing assistance. Most commonly, this has taken the form of generic advertising funded by levies on producers.

Generic advertising has been a widely-used marketing tool in many agricultural industries, both in Australia and overseas. Meat, eggs and milk are all industries where generic advertising has a long history. Producers collectively levy each other to fund generic advertising and promotion. Levies are typically self-imposed by producers and are typically set as a dollar rate per unit of production or as a percentage of farm sales. These levies are usually then administered by a government agency charged with securing the desired marketing outcomes.

The primary purpose of these advertising campaigns is to shift the demand curve to the right, increasing sales at the retail outlet. Advertising and promotion aims to do this both by providing information, and by influencing consumer preferences in favour of the promoted product thereby switching demand away from substitutes.

As with any such promotion in fishing, increasing sales at the retail outlet is a necessary condition for fishers to benefit from generic advertising. Ultimately, however, fishers derive benefit from a generic advertising if the net beach price rises. Achieving a higher net price for producers increases the returns to producer-owned capital, management, labour and the fish resources, which are in limited supply. That is, it increases the producer surplus.[21]

The legislative framework may also require that agents conform to other applicable laws. For example, in the case where a retailer wishes to vertically integrate via a takeover of a dominate processor it will be subject to the competition law as implemented via the ACCC and enforced via the courts.

The production of the rules that will cause participants to conform to legislative requirements is part of executive government. These rules essentially determine how the various agents can participate in the value chain. For fisheries, the Fisheries Department makes these rules. This is often expressed as a management plan. For the Western Rocklobster fishery, determining the annual TACC, defining, and implementing legal proportion harvested rules, fall into his category. In fisheries, an important part of this role involves assisting agents to follow the rules and gain enhanced value from the chain. For example, the Fisheries Department may undertake R&D and make it publicly available to participants in the chain. This could

[21] There may be other objectives for generic promotion. For example, promotion of fish as an alternative to red meat may be based on health considerations and the external benefits of such a switch in consumption patterns. In this case, the benefit may arise even if beach price does not increase and may be independent of whether the additional consumption is from local or imported fish.

encompass research on basic biology and sustainable harvests, on animal handling and on markets.

A successful chain will have incentives to achieve compliance along with other desirable outcomes. That is, the chain needs to have incentive compatible rules and contracts. Notwithstanding the existence of incentive compatible rules, it is also necessary to audit performance and to check compliance with these rules. Where compliance is not occurring appropriate sanctions need to be imposed through the judicial system.

Maximizing the overall performance of the chain requires that actions across all the areas of external governance be coordinated and consistent. Table 1 presents a simple illustration of the relationship between the private and government components across the various layers of the supply chain interpreted as a governance framework.

Table 1: Illustrative Taxonomy of Internal and External Governance

	Exercised by parties internal to chain	**Exercised by parties external to chain**	
Contractual	Setting standards for fishers in relation of timing of deliveries, quantity and quality.	Environmental standards including marine parks. Fisher occupational health and safety Harvest rules – quota and LPH, zonal areas, size definitions	**Legislative**
Compliance	Monitoring compliance with commercial contracts and invoking penalties for non-compliance. Court resolution and rectification in cases of dispute	Monitoring the performance of fishers and processors against rules. Enforcing compliance including compliance with licence conditions	**Judicial**
Executive	Firms in the supply chain assisting others suppliers to meet required standards. E.g., processors assisting fishers to achieve catching objectives though ex ante price signalling. Producer associations assisting members to meet these standards	Agencies providing specialized support to industry – R&D, marketing assistance, assistance negotiating cross-country agreements. Taking responsibility for the design and implementation of management plans and harvest rules.	**Executive**

An important element of supply chain effectiveness is what has been defined as the legitimacy of the governance process. This embraces both the external and internal structures. The external governance structures derive legitimacy through the establishment of laws and consistent implementation and monitoring. The need for transparency in rule making and fairness in implementation are well established within public policy. An important aspect of legitimacy is what might be termed trust, encompassing procedural justice. In fisheries management extensive consultation around changes to management regimes has been critical to establishing confidence in the ultimate management system adopted and in its ongoing implementation. The Western Rocklobster industry was subject to extensive consultation over several years as part of the move away from input controls to ITQs. As the system is being implemented ongoing consultation is still occurring around key parameters such as the legal proportion harvested. There is a direct impact on supply chain performance here. The greater the acceptance of any management regime the more likely that light-handed regulation will induce compliance, which in turn reduces management costs.

These same arguments about legitimacy also apply to the private governance within the chain. Along the chain, a mix of supply contracts exists backed by a mix of incentives and sanctions with the ultimate sanction being exclusion. Higher-trust relationships induce better outcomes with less emphasis on monitoring and punishment. As its simplest, turnover of suppliers/buyers is reduced. A key aspect of the Western Rocklobster chain is the relationship between the processors and the overseas wholesalers/distributors. The latter need to perform their role well if live product is to be delivered in the best condition possible to final customers. Failure to do so may not only damage their own business but also the reputation of the product.[22]

The role of governance in enhancing value through the supply chain

From the perspective of fishers, enhanced value occurs when the impact of governance secures improved long term returns. This could be thought of as an improved beach price, but more appropriately, given the biological constraints as improving the net present value of returns to fishers.

Potentially changes might be made at all levels of the chain as part of pursuing this objective. However, where the focus is on the role of government (external governance) and where fishers, processors, wholesalers and retailers are private firms, the potential areas of involvement are primarily in harvest strategies and marketing.

Harvest strategies ensure that harvests comply with biological objectives. Expressed in terms of maximum sustainable yield these strategies ensure that fishers operate within a long term harvest strategy that ensures an ongoing availability of resource. Where recreational fishers are able to access the resource this aspect of governance needs to incorporate a specific resource sharing strategy. The role of government in forming harvest strategies arises because of the negative externality associated with open access. Ensuring sustainable yields deals with this issue. However, insofar as the economic performance of the chain is concerned governance at this level also needs to encourage fishers to harvest the designated catch with maximum efficiency. To this end, the specific harvest rules and mechanisms chosen (e.g. quotas versus input controls) have a potentially significant impact on economic outcomes.

Marketing involvement needs to be interpreted broadly. Government plays a role in ensuring the integrity of the supply chain as part of marketing. A particular aspect of this in fisheries is accuracy in labelling by species and country/locality of origin. The transaction costs prohibit individual fishers from policing this in most fisheries. Similarly to the extent that sustainability and relate quality control certification is an important aspect of marketing

[22] Appropriate incentive compatible contracts are an important link in this. For example in supplying live lobster to customers in Hong Kong, distributors and buyers cite mortality as a critical cost. Both recognize that some mortality is likely and the reasons may be related to handling by either the distributor/buyer or both. Typically, some sharing is built into the supply contract. A typical arrangement is one where the distributor bears the first 55 of mortality costs and after that they share it 50; 50. Hence ,if mortality is 15% the distributor bears 10%, the customer 5%. Source: Melinda Ng, WorldWide Seafoods pers.comm.

government has played a role. Again, the transaction costs of individual fishers organising to do this would be prohibitive.

Generic advertising of fish falls into two categories. Where an external health benefit is being pursued, government involvement is based on a perceived market failure and the strategy is designed with this in mind. Benefits to fishers would be a by-product benefit. However, where advertising of fish can to shift the demand curve to the right is specifically developed to achieve benefit for fishers, the rationale for government involvement is that the transaction costs of fishers organizing to collect levies and fund advertising would be too high in the absence of government support. In part, this will because successful generic advertising has the attributes of a public good and this encourages free riding.

The role of wholesalers and processors and retailers is more complex. Whilst critical to the chain, they are private firms operating as ain any other market. Governance in this case is arguably limited to ensuring compliance with all relevant laws and regulations including ones specially developed for the fishery. For example, retailers would be expected to comply with fish labelling and quality regulations. Processors would be expected to comply with harvest monitoring regulations that specified licenced fishers and required processors to provide purchase records to allow monitoring of quota.

At another level, it is important to ensure that processors, wholesalers and retailers operate in a competitive environment and cannot exercise monopoly or monopsony power. This is not a fisheries governance issue per se but a general market governance issue usually operated through the appropriate competition laws.

Understanding the structure of and economic relationships within the supply chain is a necessary condition for assessing which aspects of governance impact on economic performance. It is a basis for assessing how governance arrangements might be changed to improve economic performance in the chain.

In what follows the supply chains for both Western Rocklobster and the West Coast Demersal Scalefish Fishery in Western Australia are considered. The focus is on looking at economic aspects of the supply chain and the role that governance, especially harvest strategies play in affecting the economic performance of the chains.

Supply chain Models as a coherent framework for evaluating Governance in Western Rocklobster.

Overview of Western Rocklobster Industry

The Western Rocklobster (Panulirus Cygnus) and the Southern Rocklobster (Jasus edwardsii) are the two major rock lobster species caught in Australia. A small volume of Tropical Spiny Lobster (Panulirus spp) is also caught.

Table 2 shows the recent catch history for the various lobster species in Australia. The well documented decline in Western Rocklobster catches is illustrated by the fall to the current catch level of just over 5,000 tonnes from the historic highs of nearly 14,000 tonnes. These new lower catch levels have been built into the harvest rules in the model results presented below. Since 2000, the average price for Western Rocklobster has been $27 while for Southern Rocklobster it has been $42. More recently, the price has been higher.

The Western Rocklobster industry in Western Australia is primarily an export oriented industry. In recent years, the bulk of the catch has been exported live to China and Hong Kong. Export to China via Hong Kong has been common, but export direct to China is now occurring.[23] In 2011, live exports to Hong Kong SAR accounted were 2,473 tonnes at an average fob price of $52/kg. Live exports to China were 738 tonnes at an average fob price of $47/kg. Total exports were 3,527 tonnes at an average fob price of $51/kg.

The major processor and exporter is the Geraldton Fishermen's' Cooperative (GFC).The GFC is an integrated processor, distributor and marketer and accounts for about 65% of the catch.

The markets to which Southern and Western Rocklobster are exported, notably China and Hong Kong, source lobster from around the globe; from Australia, North America (Canada, the USA), South America (Chile) , South Africa, Europe (UK, Scotland, France) and Asia (Indonesia, Vietnam). Globally the lobster market includes a wide range of rock lobster species and Australia accounts for only a small percent of production.

[23] In part this reflects government policy with the Chinese government encouraging the direct export of product to China.

Table 2: Recent Lobster Catches by Species in Australia 2000-2010 (tonnes)

		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Western Rocklobster	Indian Ocean, Eastern	14605	11353	9050	11477	13745	12304	10441	8676	8990	7635	5502
Green rock lobster	Pacific, Southwest	117	103	103	122	108	99	101	110	122	122	122
Metanephrops lobsters nei	Indian Ocean, Eastern	39	105	88	-	63	61	42	43	15	37	51
Metanephrops lobsters nei	Pacific, Western Central	-	-	9	-	16	10	18	8	24	29	...
Slipper lobsters nei	Indian Ocean, Eastern	0 0	-	-	-	-	27	22	15	20	16	31
Slipper lobsters nei	Pacific, Southwest	0 0	0 0	0 0	0 0	0 0	9	6	2	2	3	3
Slipper lobsters nei	Pacific, Western Central	...	...	...	...	...	56	56	36	33	22	12
Southern rock lobster	Indian Ocean, Eastern	4756	4677	4403	4271	4500	4426	4258	4294	4099	3497	4368
Tropical spiny lobsters nei	Indian Ocean, Eastern	-	-	-	-	-	-	-	-	-	-	-
Tropical spiny lobsters nei	Pacific, Western Central	359	274	330	1211	1471	1061	768	675	655	444	429

Source: FAOStat

Management of the Western Rocklobster Industry

Management History and Move to ITQs

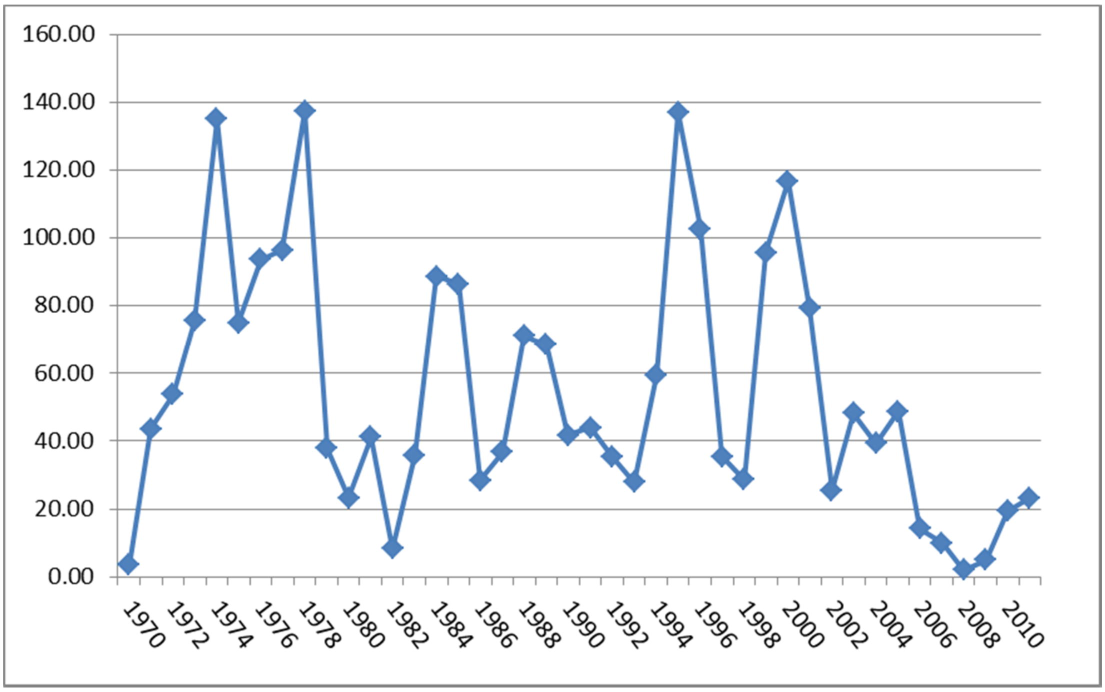
The Western Rocklobster fishery is predominantly a commercial fishery that is divided into three zones – A, B and C, with the recreational catch being less than five per cent of the total take from the fishery. It was one of the first fisheries in the world to be converted from open access to a system of limited entry with the number fishing boat licences limited since 1963. For decades preceding the 2010/11 season, the fishery was managed using input controls that controlled catch levels indirectly by capping overall nominal effort (measured as pot lifts).

The primary input controls were a limit on the total number of pots, and available fishing days. Together, they placed an overall cap on total allowable effort (TAE). Historically, the input management regime focused on setting the total allowable effort levels aimed at delivering a sustainable breeding stock, rather than restricting catch to a given level. The number of effort units held by an operator was used to determine the number of pots that could be operated. In effect, each unit represented a fixed percentage share of fishery TAE.

Units were fully transferable and tradeable, and an active market for the lease and purchase of units enabled operators to adjust fleet configuration in response to changing economic conditions. This system of management was known as an Individually Transferable Effort (ITE) system. For most of this time, the annual catch ranged from around 8,000 to 14,500 tonnes, and in recent years, prices have varied from around AUS$19 to $34/kg.

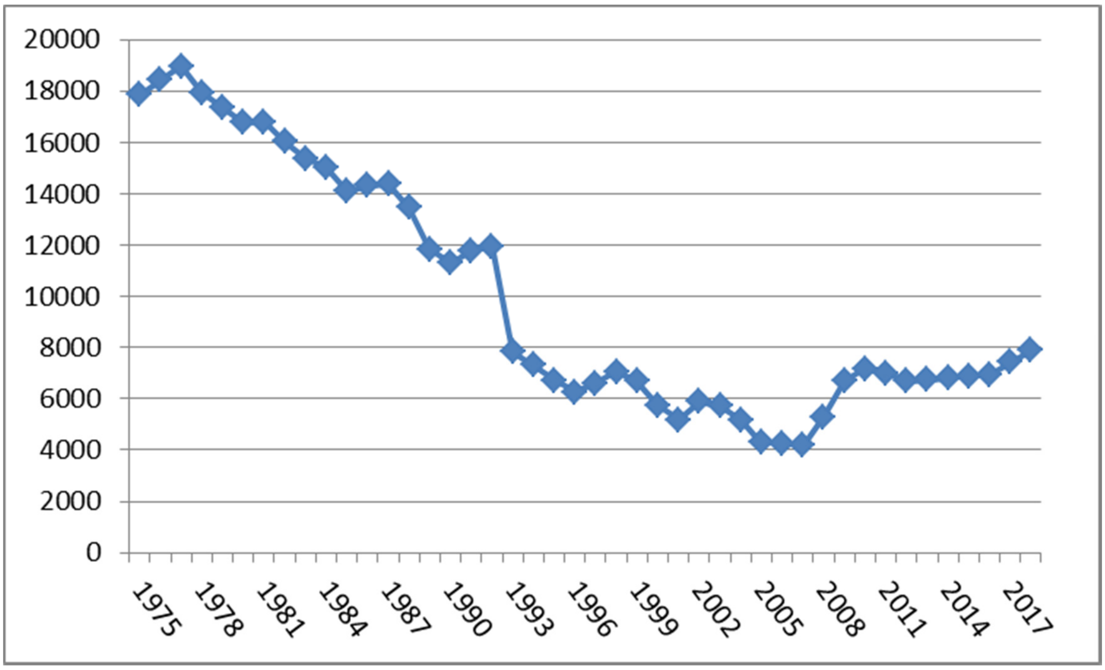
An important element in this system has been fishery stock assessment and prediction of future catch levels based on a puerulus settlement index derived from monthly samples of post larval settling 3 to 4 years earlier. This enabled management to consider expected recruitment trends when contemplating options to control effort levels, which were adjusted periodically to ensure sustainability. During the period from 2006/07 to 2010/11, this predictive ability was especially important when puerulus settlement declined to unusually low levels. The recent trends in the puerulus settlement index and closing legal biomass are shown in Figure 4 and Figure 5

Figure 4: Coast Wide Puerulus Settlement Index (PSI)



Source: Department of Fisheries, Western Australia.

Figure 5: Estimate of Closing Legal Biomass for Western Rocklobster



Source: Department of Fisheries, Western Australia.

Following the lowest puerulus settlement on record (40 years) during the 2008/09 settlement period, substantial changes were made to the management of the fishery for the 2008/09 and 2009/10 seasons. It was decided that a much lower catch level needed to be targeted to ensure the protection of breeding stock, as well as to provide for a carry-over of stock into future seasons. To achieve this aim, severe effort reductions were imposed in the 2008/09 fishing season by drastic cutbacks to the number of available fishing days and pot numbers, as well as other measures such as increased protection of large females. These restrictions were subsequently increased for the 2009/10 season in order to achieve a nominal target catch of 5,500 tonnes. The net effect of these reductions in TAE were reductions in nominal fishing effort of 44 and 73% in 2008/09 and 2009/10 compared to 2007/08. This not only reduced catch levels in the fishery, but also resulted in a significant carryover of legal lobsters into future years when lower recruitments to the fishery might be expected.

Current Management Arrangements

In recent years, major changes have been made to the management of the Western Rocklobster fishery (WRLF). Following a collapse in the breeding stock, drastic measures were introduced in the 2008/09 fishing season to reduce fishing effort. Subsequently, the management system has been in transition from an ITE based system to a system based on direct catch controls and individual transferable quota (ITQ) in which units are associated with a right to catch a specified weight of lobsters. This new ITQ based management regime that uses catch limits was introduced on 15 January 2013.

Subsequently, a Harvest Strategy and associated control rules (HSCR) for setting annual TACC for the Western Rocklobster fishery for this new management system has been proposed, but is still under consideration. Development of the Harvest Strategy is being coordinated by the Western Australian Department of Fisheries. A preliminary draft strategy published in February 2012 was outlined in Fisheries Management Paper (FMP) No. 254. In December 2013, a refined draft strategy with more detailed proposals was presented in FMP No. 263 for industry and community comment and feedback. It is expected that the harvest strategy for the Western Rocklobster Managed Fishery will be finalized in 2014. At its core, this Harvest Strategy will comprise a set of decision control rules for annually setting the Total Allowable Commercial Catch (TACC).

The main purpose of the HSCR is to provide a transparent set of principles to guide the TACC setting process that will make this process more understandable to fishers and other stakeholders. While the set of principles to guide the TACC setting process are still to be formally approved, it is clear from Fisheries Management Papers 254 & 263 that two key objectives of biological sustainability and increased economic returns will underpin the Harvest Strategy and Control Rules (HSCR) framework.

Market and Prices

Overview of Lobster Market and pricing issues

The lobster market is a competitive world market. Lobster is sold live or in a variety of processed forms including whole cooked frozen lobster, whole raw frozen lobster, frozen tails.

Wild capture product from Australia competes with product from New Zealand, the USA, Canada, South Africa and other nations for market share in major destination markets such as Europe, North America, Japan, Taiwan, China and Hong Kong SAR. Emerging competition from aquaculture is centred on countries such as Vietnam.

The mix of product and destinations has changed over time. Traditional export markets for Australian lobster such as Japan have scaled back in recent years to be replaced by China and Hong Kong SAR. Live product is a focus for exports to China and Hong Kong SAR.

A particular issue for producers exporting lobster in global markets is the nature of price formation and the identification of the closes substitutes for their products. If consumers see the various lobster products as close substitutes, albeit with price differentials to reflect size and quality, then they will readily switch away from a product whose price has risen relative to a substitute. In this case, the law of one price prevails In such circumstances, the ability of an individual supplying jurisdiction to exert market power is limited and, ceteris paribus, restricting sales will result in very little price increase . Demand would then be price elastic and revenue will fall. Alternatively, if a jurisdiction provides a product (e.g. a particular live lobster species) for which consumers perceive no close substitutes then some market power may exist and the demand may be relatively less price insensitive and restricting supply may deliver a significant price increase? If demand is price inelastic then revenue will increase.

Prima facie, as with all agricultural commodities, we expect the global market to be composed of products that are perceived as good substitutes. Although price differences between origins/species/ will persist, these will be maintained by the willingness of consumers to switch away from a product if its price becomes relatively high. Ceteris paribus to protect the position of any one product, its price must remain competitive. The overall price level and the relative price of particular species/origins within it, will respond to the overall balance between global demand and supply.

Recent trends in global production and trade are assessed below along with recent price trends. The pattern of Australia's lobster trade is considered in relation to major buyers, major competitors and recent price trends. The same assessment is then made for Western Rocklobster.

Finally, an analysis of a variety of price data is made to determine, at least indicatively, if the law of one price hold for lobster prices. This is done by testing for cointegration across a time series of lobster prices. A preliminary assessment of the price elasticity of demand is made for Western Rocklobster. Results are placed in the context of information obtained from interviews with lobster importers and distributors in Hong Kong SAR.

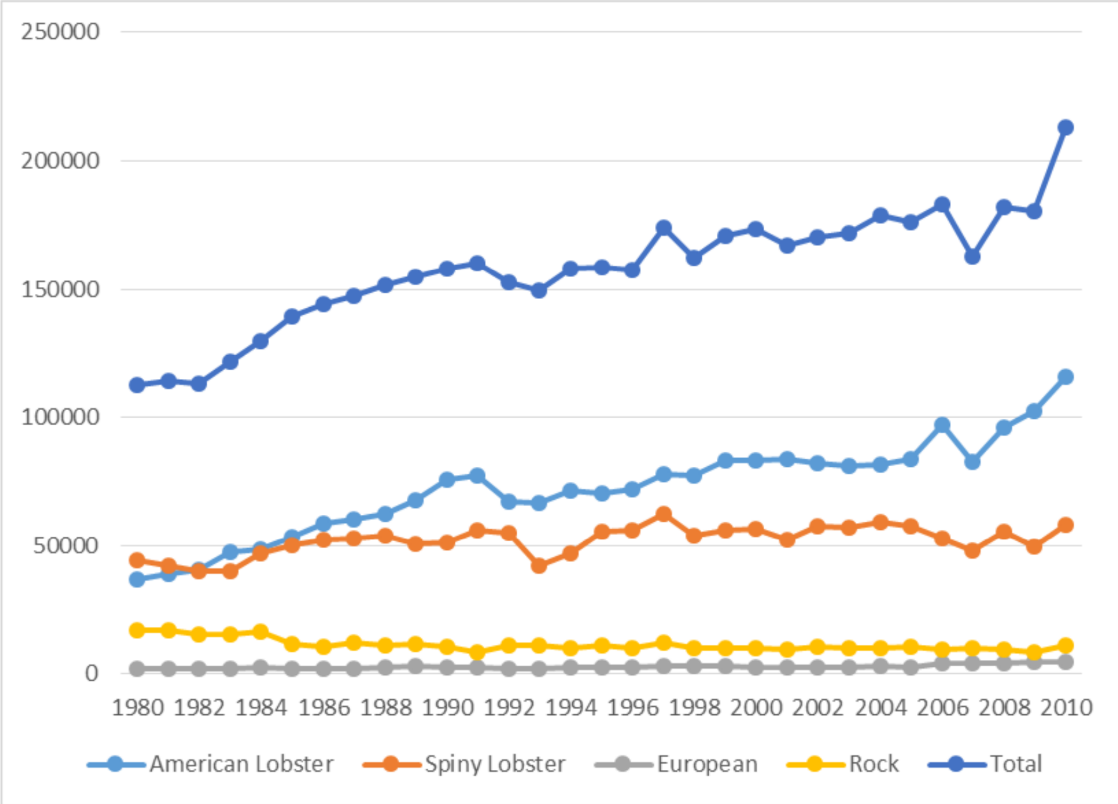
Global Lobster Market

Global Production

Globally around 280,000 t of lobster is produced annually. The capture production trend since 1980 is shown in Figure 6. There are four main species or species groups; American (species caught in Atlantic Canada and the U.S. northeast), spiny, rock and European dominate production. American lobster accounts for about 54% of total supply, with spiny lobster (a clawless warm water species) accounting for 27% Rock (also clawless) and European lobster account for about 5% and 2%, respectively.

In the last twenty years, global capture production has increased by about one-30 percent. American lobster production accounts for most of the increase. Its production has increased by around 53 percent over the period rising from 75,000 t in 1990 to 115,000 t in 2010. Over the period spiny lobster production held steady around 65,000 t. Western Rocklobster supply was steady in the range 10,0000t to 12,000t.

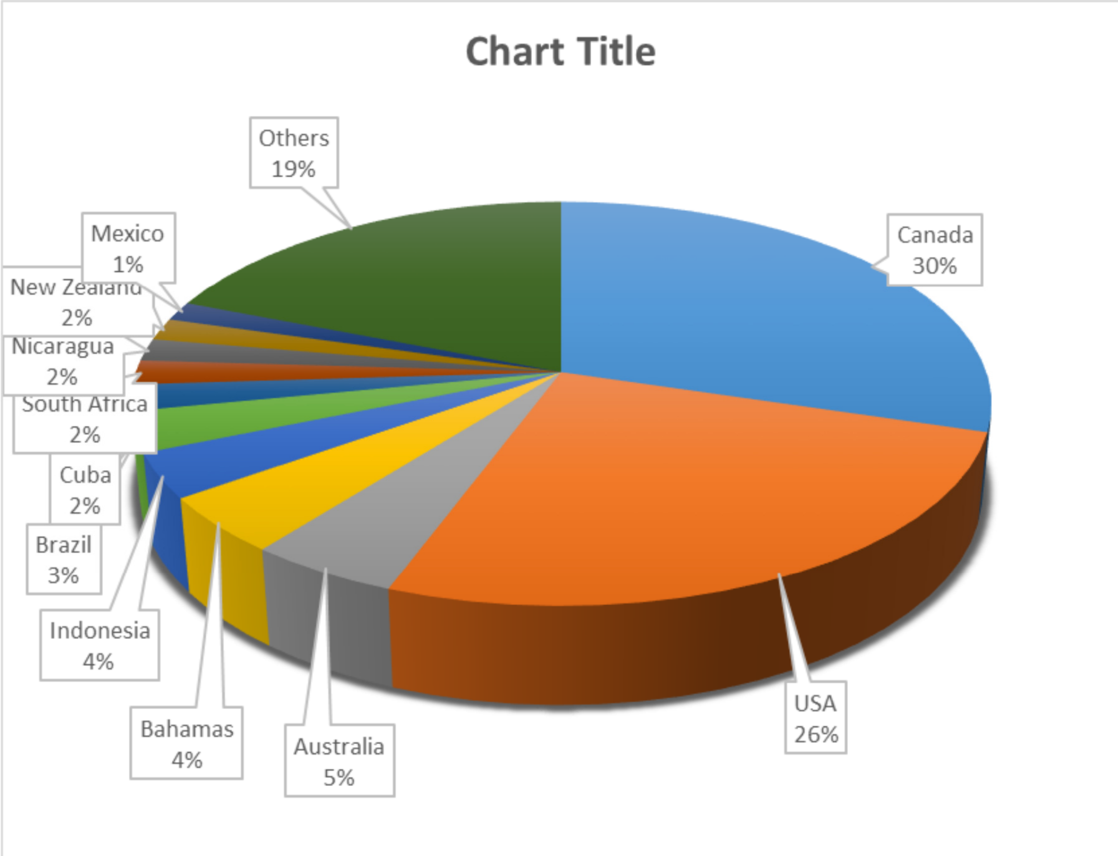
Figure 6: Global Capture Production of Lobster



Source: FAOStat

The breakdown by major producing countries is given in Figure 7. Canada (30%) and the U.S. (26%) are the world's leading suppliers and the source of American lobster. Australia produces around 5% of supply (as rock lobster). A range of countries in the Caribbean and South America contribute to spiny lobster production accounting for 2-4% of global production on an individual basis.

Figure 7: Global Production of Lobster by Country



Source: FAOStat

Global Demand

Lobster is a product typically associated with higher income earning individuals and countries. Historically this has meant that the main markets were North America (U.S. and Canada), Western Europe (UK, France, Belgium, Spain, Italy, Netherlands and Germany) and the higher income areas of Asia (mainly Japan, Hong Kong and South Korea). A major change in recent years is the emergence of China mainland as a significant market for lobster and one with considerable growth potential as China continues to grow and real income per head increases.

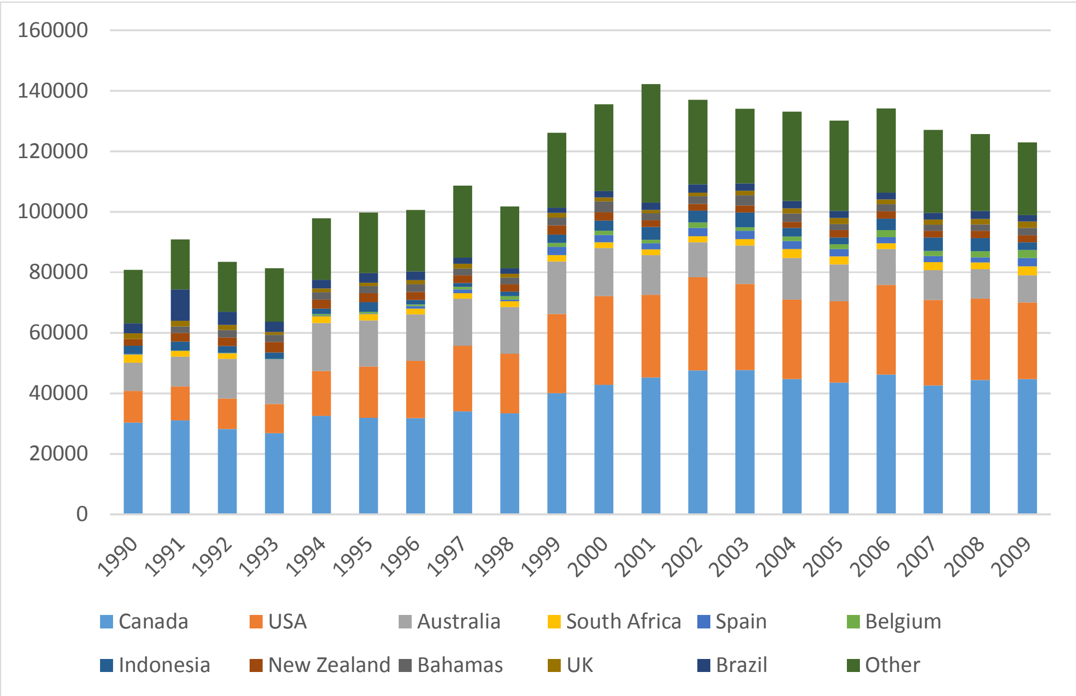
Global Trade

Lobster is traded globally in a number of product formats. It is traded as whole lobster (live fresh chilled and frozen) as tails (frozen uncooked and cooked) and in meal preparations.

The pattern of trade can considered in terms of both export and import patterns. Recent export trends are shown in Figure 8. Canada is the dominant exporter with the bulk of its exports going to the US. The US is the second biggest exporter. Australia is the third biggest exporter and exports virtually all of its production. Export volumes have contracted in recent years reflecting difficulties in some production areas especially Western Rocklobster. After the major producers are accounted for, the export volumes shrink to a range of countries such as South Africa and New Zealand where volumes are typically in the range 2,000 to 3,000t.

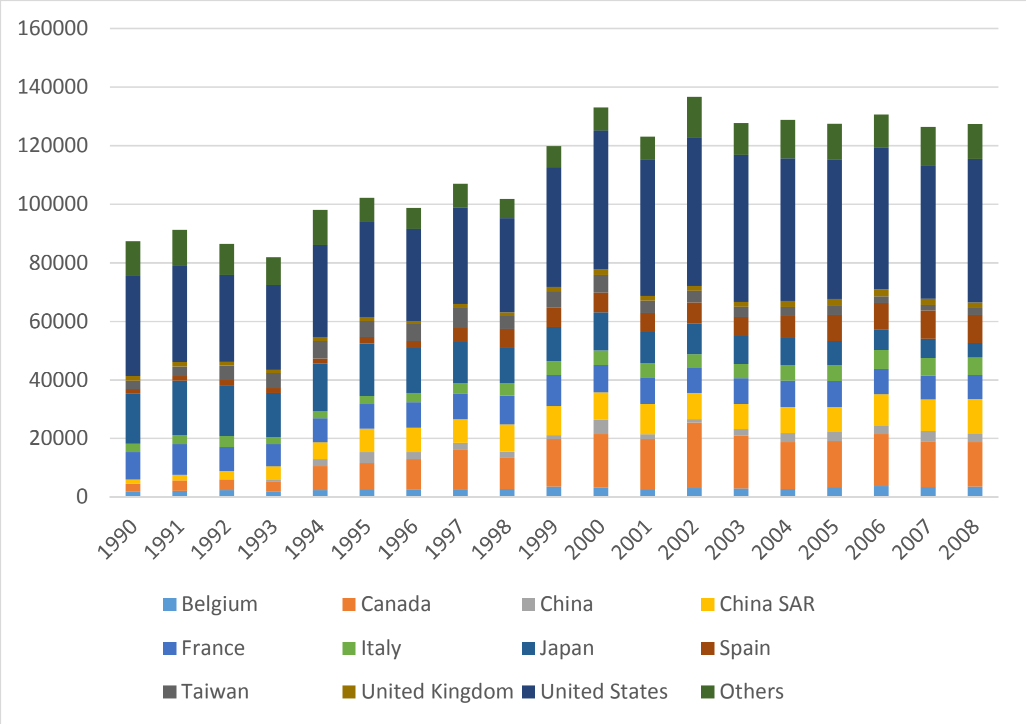
Import trends since 1990 are shown in Figure 9. The United States is the biggest exporter at around 49,000 t in 2009 followed by Canada (15,000t) and Hong Kong SAR (11,700t). China has imports of 3,000t. Japanese have declined significantly from over 18,000t in 1991 to 5,000t in 2009. European countries are significant importers with Spain (9.500t), France 98,100t) Italy (5,900t) dominant.

Figure 8: Global Exports of Lobster



Source: FAOStat

Figure 9: Global Imports of Lobster

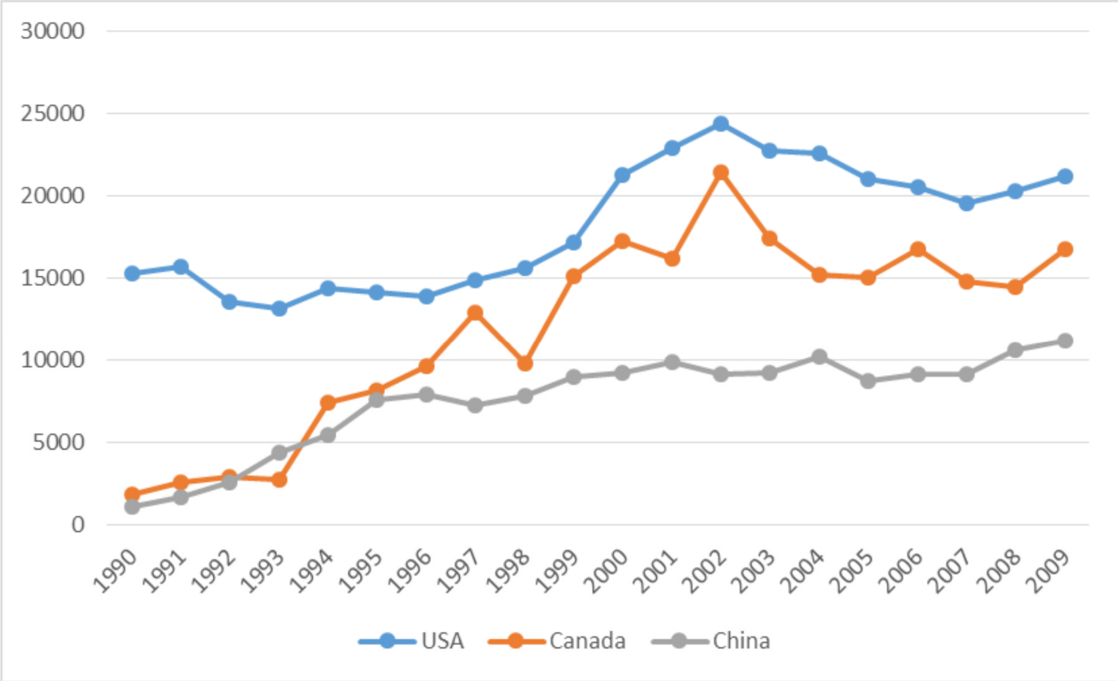


Source: FAOStat

Live Imports

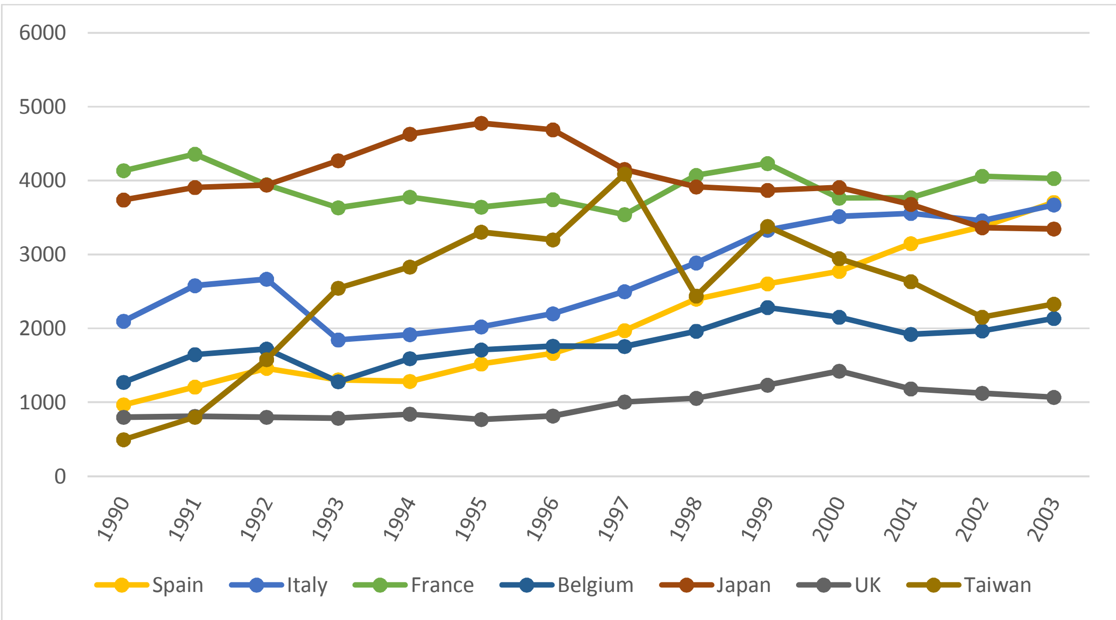
The U.S. is the dominant market for live lobster, with imports of around 22,000t. . Canada is a substantial importer. Much of this comes from the US for processing operations and this is re-exported as frozen product. China (including Hong Kong SAR) has emerged as the next major market with around 11,000t. The growth in China imports is shown in Figure 10. Other countries are considerably less in import volume. Spain, Italy and France are in the 4,000t to 5,000t range, with American lobster imported from the U.S. being a major source of imports, Belgium is around 2,000t. Japanese imports have fallen by nearly 50 percent over the period. These trends are shown in Figure 11.

Figure 10: Global Imports of Lobster - USA, Canada and China



Source: FAOStat

Figure 11: Global Imports of Lobster - Other Major Importers



Source: FAOStat

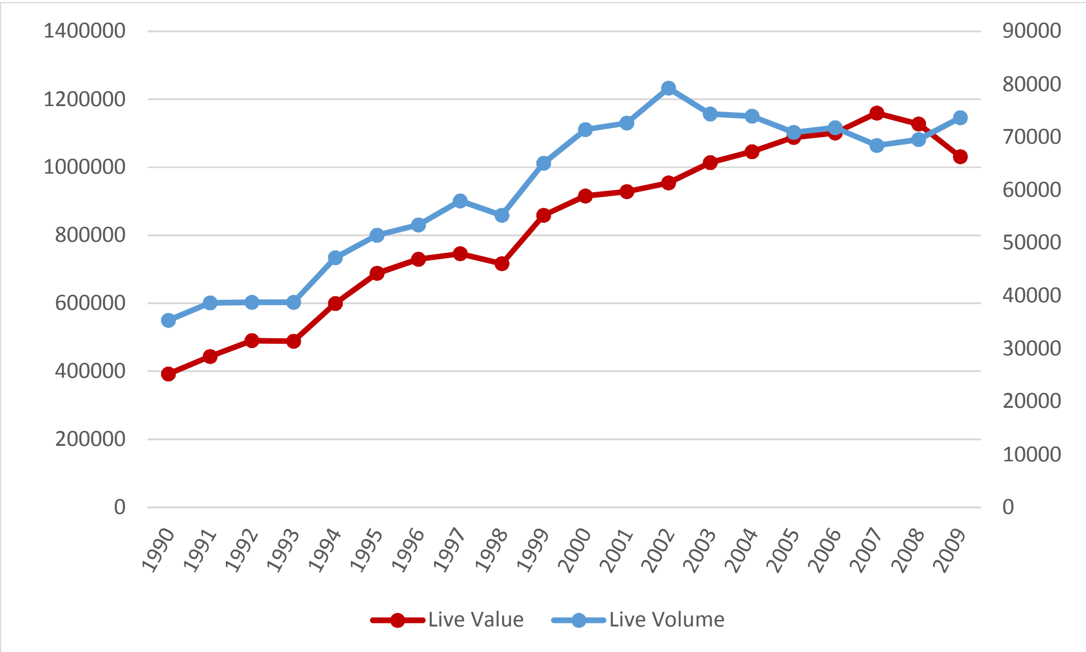
Global Demand and Supply and Prices

In general, the data suggest that global demand for lobster has kept pace with supply, providing a basis for rising nominal prices over the period since 1990. There is a marked decline in prices in the 2008 to 2009 period even though volumes increased, which is interpreted as the impact of the GFC on demand.

Over the period 1990 to 2007 global import volume doubled while value tripled Average import prices increased from US$11.00/kg to US$17.00/kg, an average increase of 3% per year. At this average rate of increase, nominal price increases were just in line with inflation. [24]

Over the whole period to 2009 price growth falls to just over 1% reflecting the price dip in the latter two years. Since 2009, some price recovery has occurred as individual country data presented below shows.

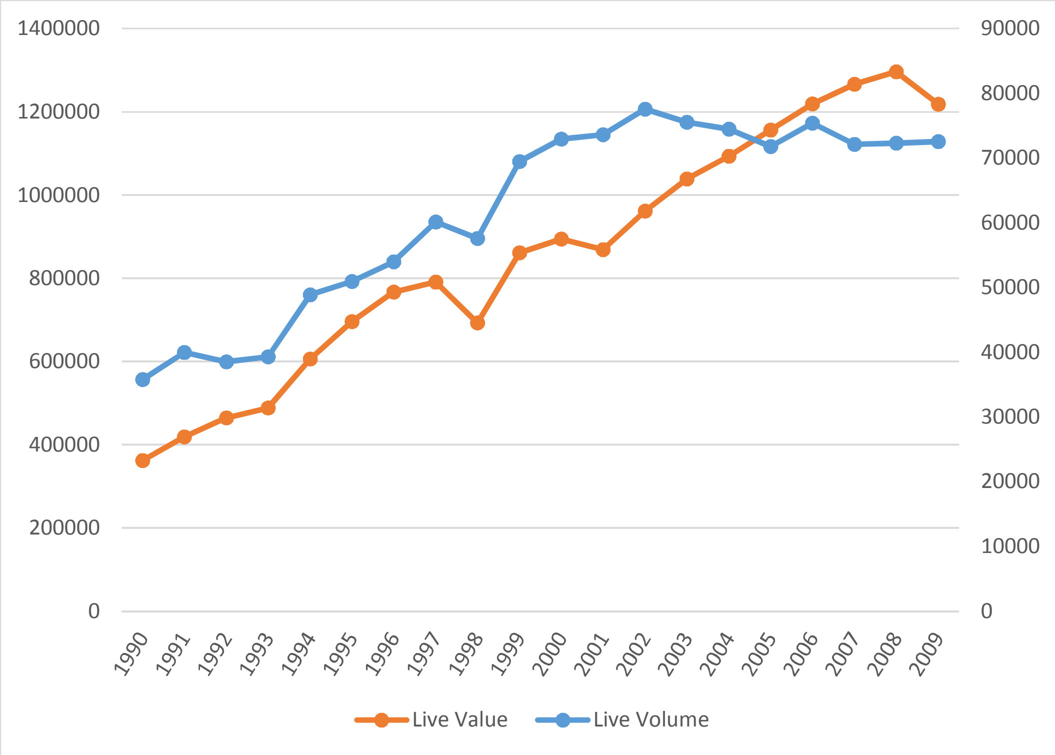
Figure 12: Annual Volume and Value of Live Imports of Lobster



Source: Source: FAOStat

[24] This is to be expected of any market in broad equilibrium over time. Prices move in line wit costs maintaining profit margins.

Figure 13: Annual Value and Volume of Live Exports of Lobster (all species)



Source: FAOStat

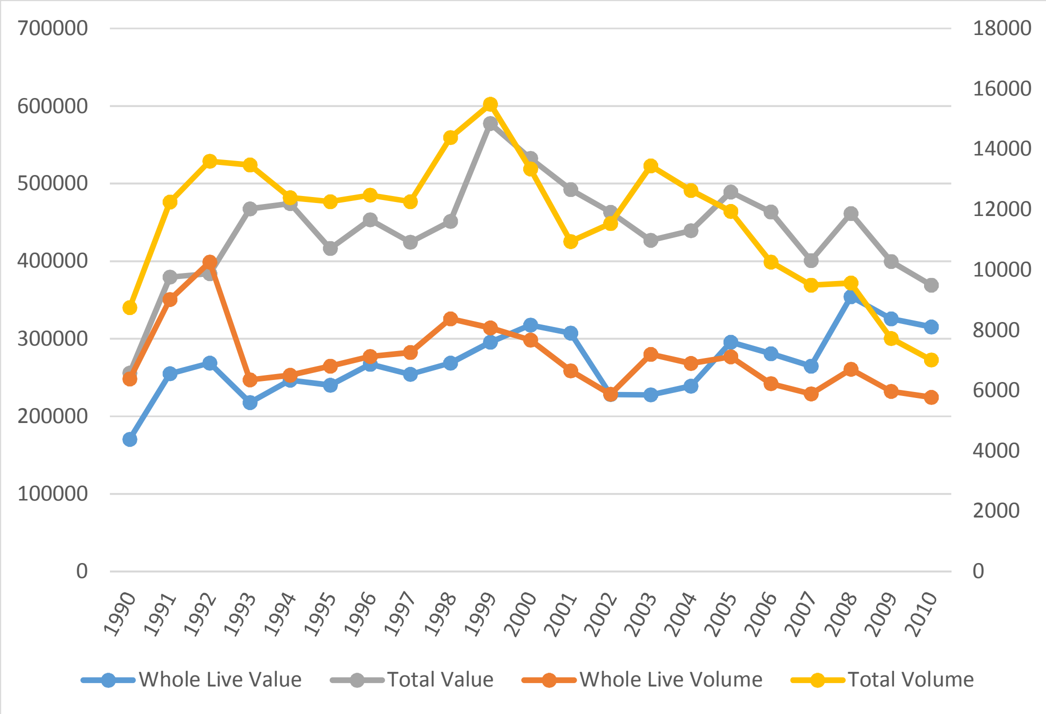
Australian Lobster Market

Lobster Exports

The recent pattern of lobster exports in Australia is given in Figure 14 for both live lobster and the whole market for lobster in all forms. The average nominal price for live and across the total production in all forms is shown in Table 3. Prices for whole live lobster have grown ahead of frozen and cooked prices with the gap widening in recent years.

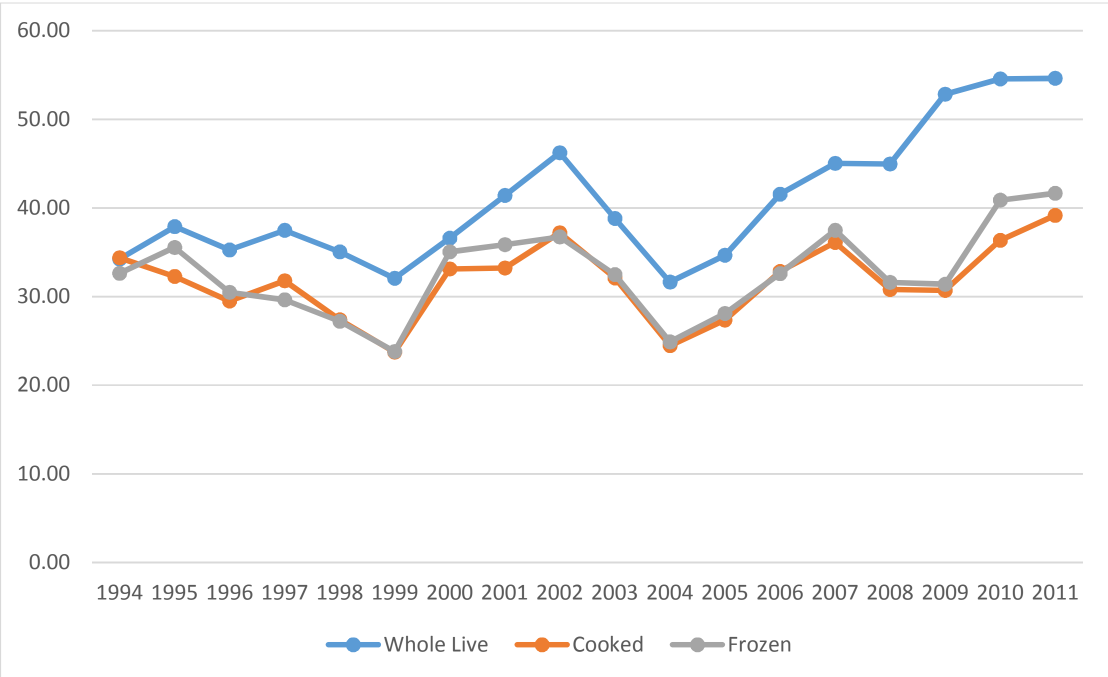
Over the period 1990 to 2011 the average rate of price growth for whole live was 4.2 percent per annum while cooked it was 3.3 percent per annum. Both are ahead of the domestic inflation rate, which was 2.6% pa over the period.

Figure 14: Recent Exports of Lobster (all species) - Australia



Source: Australian Fisheries Statistics

Figure 15: Australian Export Prices for Lobster (all species)



Source: Australian Fisheries Statistics

Major Markets for Australian Lobster

The major current destination for Australian lobster is Hong Kong SAR. The split of Australian lobster exports across major markets is shown in the following tables for whole, frozen, cooked and lobster tails.

Hong Kong SAR dominates the whole lobster market accounting for 69 percent of export volume. China accounts for another 23 percent. Japan accounts for 39 percent of the frozen lobster export market with the United States at 19 percent and Hong Kong and Taiwan at 17 percent each having the next most important shares. Taiwan (59%) and Japan (22%) dominate the cooked lobster exports and the United States (93%) accounts for most of the tails. Prices received in each market for whole lobster are shown in Table 3.

Table 3: Whole Lobster (all species) Export Destinations 2010-11

Lobster Exports, Live Fresh Chilled,				
	Volume (tonnes)		Value ($'000)	$/Kg
Hong Kong	3984	69%	223032	56.0
China	1334	23%	68263	51.2
Japan	197	3%	10369	52.5
Other	72	1%	4694	65.6
Taiwan	68	1%	3068	44.9
France	57	1%	2424	42.4
Singapore	25	0%	1449	58.8
Malaysia	20	0%	1336	65.6
United Arab Emirates	11	0%	574	54.0
United States	4	0%	166	47.4
Total	5772		315374	54.6

Source: Australian Fisheries Statistics

Table 4: Cooked Lobster (all species) Export Destinations 2010-11

Lobster Exports, Cooked				
	Volume (tonnes)		Value ($'000)	$/Kg
Japan	60	39%	2496	41.9
United States	29	19%	1333	46.1
Hong Kong	27	17%	998	37.6
Taiwan	26	17%	1038	40.0
Mauritius	10	6%	413	42.0
Other	1	1%	38	47.8
China	0	0%	3	40.9
Total	152		6320	41.7

Source: Australian Fisheries Statistics

Table 5: Frozen Lobster (all species) Export Destinations 2010-11

Lobster Exports, frozen				
	Volume (tonnes)		Value ($'000)	$/Kg
Taiwan	290	59%	11 515	39.7
Japan	108	22%	4 203	38.8
Other	58	12%	2 169	37.1
Hong Kong	21	4%	852	39.8
Singapore	10	2%	399	38.6
Total	489		19 138	39.2

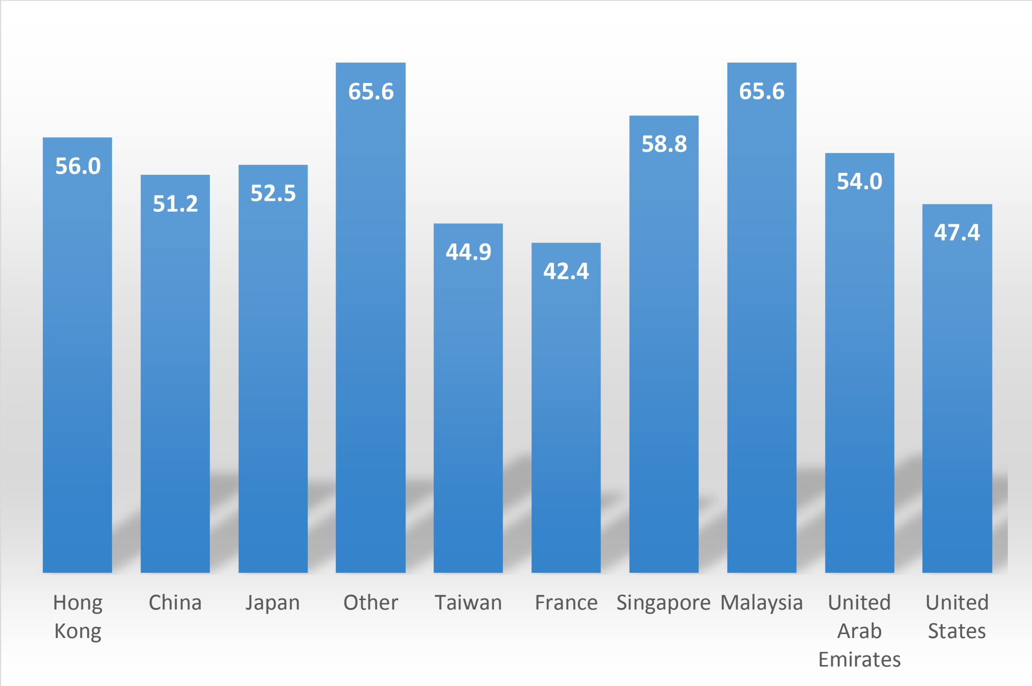
Source: Australian Fisheries Statistics

Table 6: Lobster Tails (all species) - Export Destinations 2010-11

Lobster Exports, Tails				
	t		$'000	$/Kg
United States	350	92.7%	22 189	63.3
Japan	9	2.5%	765	80.9
Hong Kong	9	2.5%	433	46.2
Other	9	2.3%	570	65.8
France	0	0.0%	0	
United Kingdom	. 0	0.0%	0	
Total	378		23 957	63.4

Source: Australian Fisheries Statistics

Figure 16: Export Prices for Whole Lobster (all species) by Market 2010-11

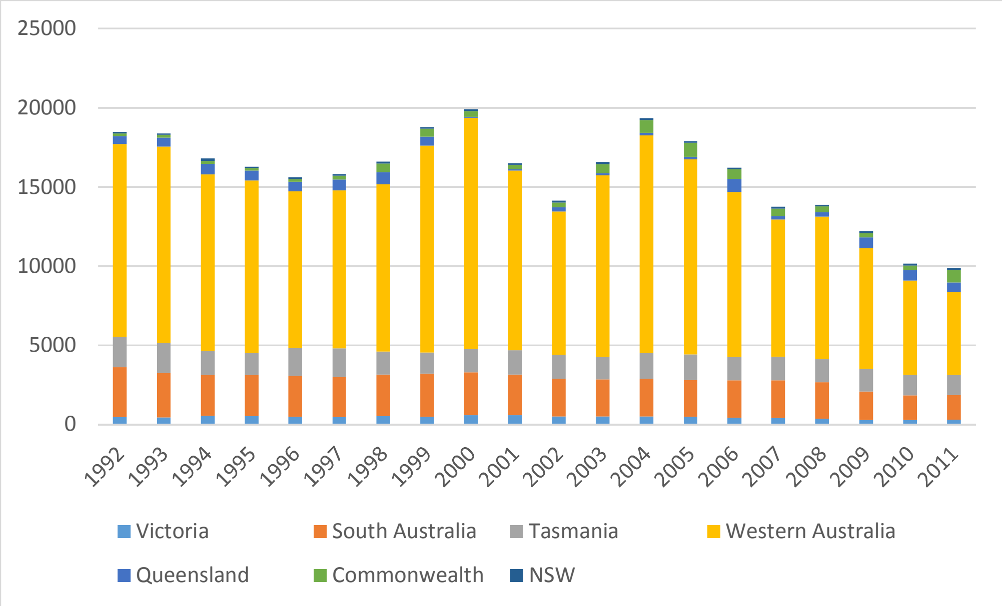


Source: Australian Fisheries Statistics

Production and Prices

The major production areas for lobster in Australia are Western Australia and South Australia. Western Australia produces the Western Rocklobster. (Panulirus Cygnus), which is one of the family of 'spiny' lobsters. They are sometimes called 'crayfish' or 'crays'. South Australia, Victoria and Tasmania harvest Southern Rocklobster (Jasus edwardsii) which is also the principal lobster caught and exported from New Zealand. Tropical lobster is primarily from Queensland and Commonwealth fishing areas. Australian production by State is shown in Figure 16. Lobster production peaked in the 1999-2000 period. Since 2004, production has declined driven primarily by the reductions in the Western Australian catch.

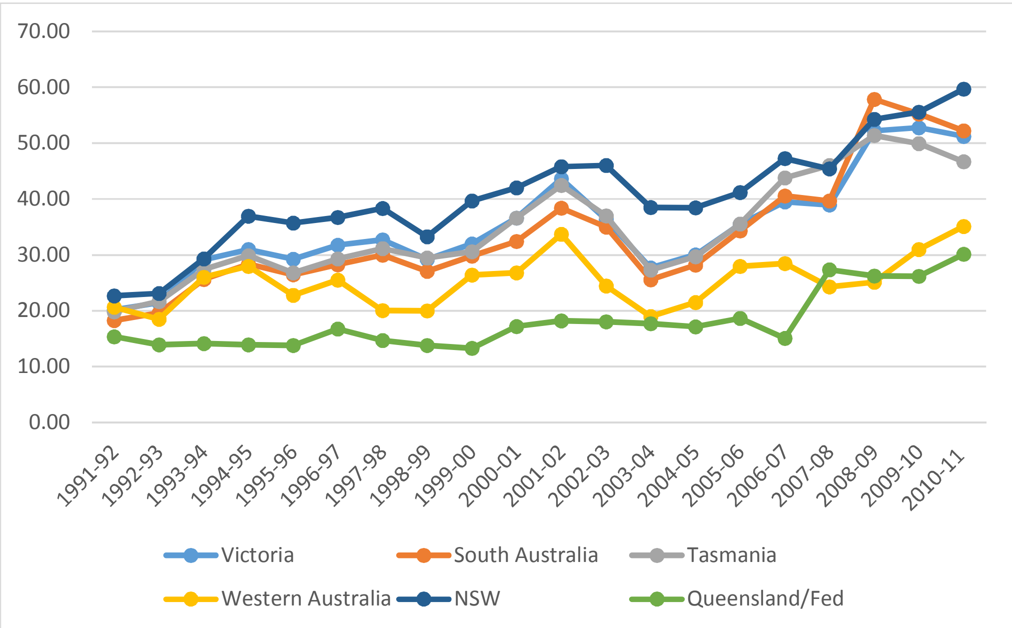
Figure 17: Australian Lobster (all species) - Production by State.



Source: Australian Fisheries Statistics

The implied price can be derived from the catch and value of catch data. These prices by State are shown in Figure 17.

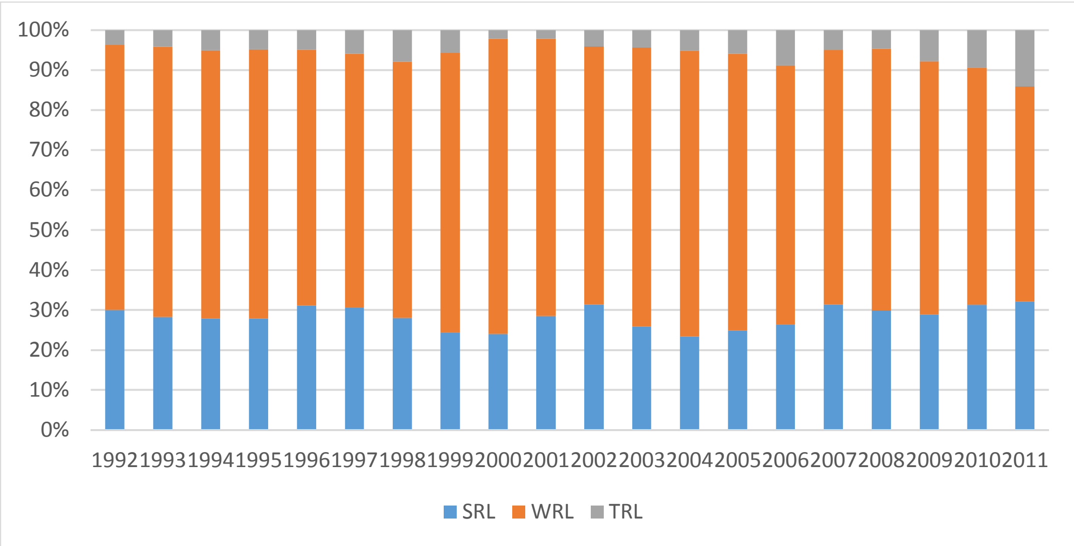
Figure 18: Price for Lobster (all species) by State



Lobster production by species share is shown in Figure 18 based on assigning South Australia, Victoria and Tasmania as southern rock catch, Queensland and the Commonwealth as tropical rock catch and Western Australia as western rock catch.

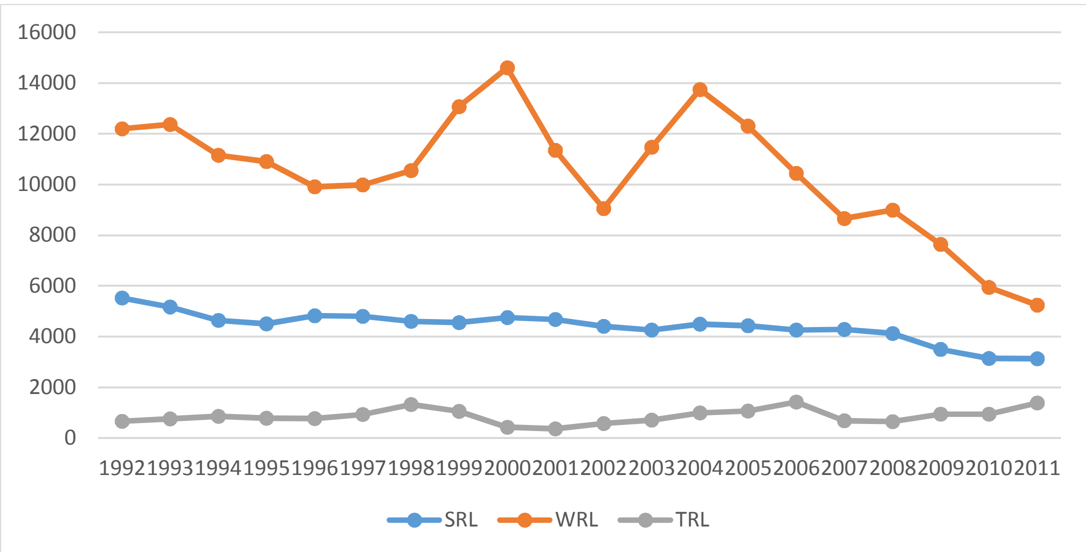
Actual tonnages are shown in Figure 19. The declining production of Western Rocklobster in recent years is highlighted. It has resulted in the production share of Western Rocklobster declining although it is still is the dominant species. Between 2004 and 2011, its share of production fell from 71 percent to 53 percent.

Figure 19: Lobster Production by Species – Production Share



Source: Calculated using data from Australian Fisheries Statistics

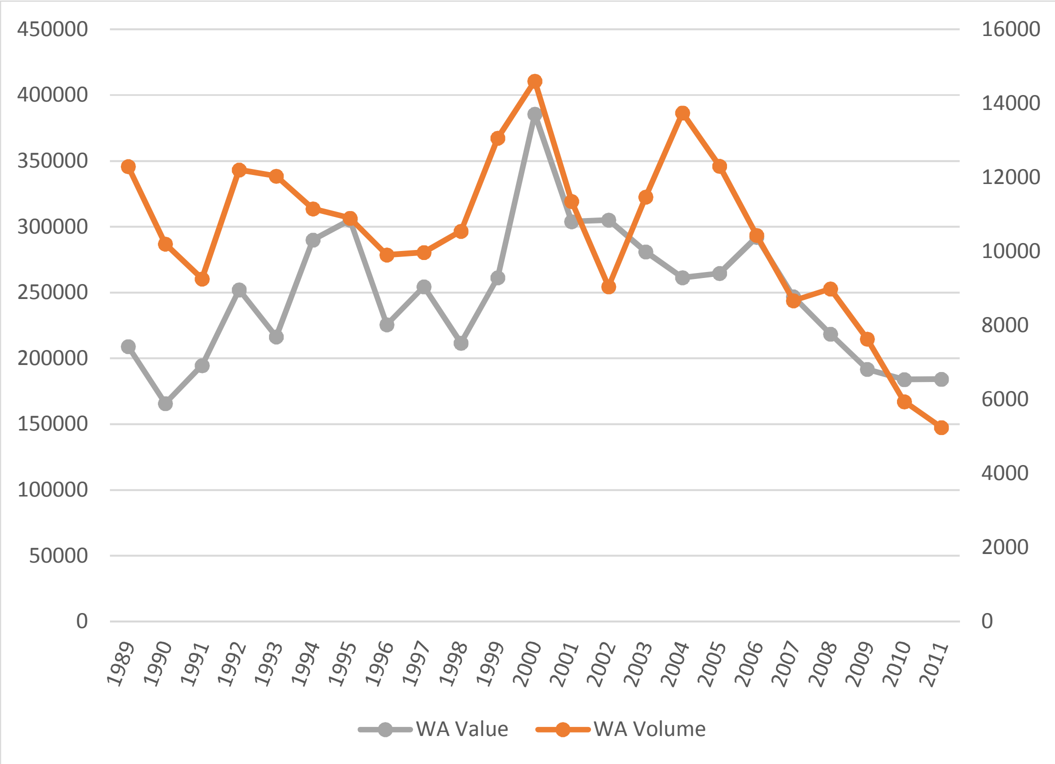
Figure 20: Lobster Production by Species - Tonnage



Source: calculated using data from Australian Fisheries Statistics

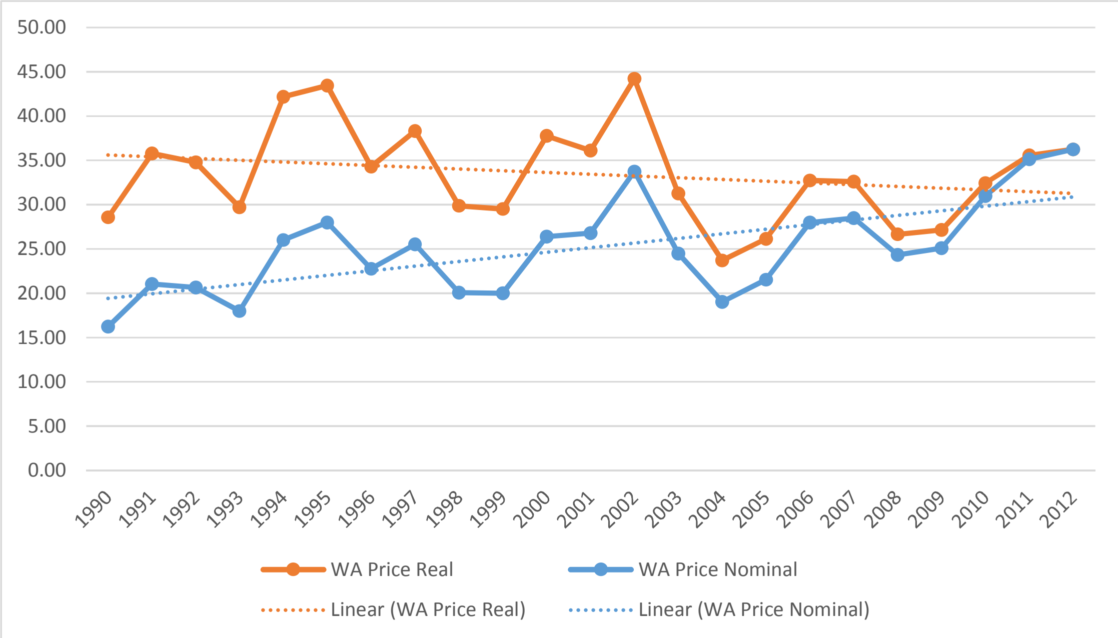
The time series for volume and value for Western Rocklobster is shown in Figure 21. The average nominal price and real price adjusted using the CPI over the same period is shown in Figure 22. Over period 1990 to 2012, the average price increases were 3.7 percent per annum in nominal price and 1 percent per annum in real terms. Average prices of the period were $25 per kg nominal and $33.4 per kg real. The best fitting linear trends are also shown.

Figure 21: Western Rocklobster Production and Value of Harvest



Source: Australian Fisheries Statistics

Figure 22: Western Rocklobster Price, Nominal and Real



Source: Australian Fisheries Statistics and ABS

Lobster Products as Substitutes\Law of One Price

The simulation model presented below simulates the interaction between harvest rules and economic outcomes for catching, processing and marketing sectors over a 46 year period on an annual basis.

It requires a sub system that specifies the lobster price for Western Rocklobster. The majority of Australian lobster, including virtually all of the Western Rocklobster is exported to Hong Kong SAR (69%) and China (22%). In that market, there is competition from variety of lobster species/producers. Western Rocklobster competes with a range of other products including:

- Southern rock from Australia
- Southern Rocklobster from New Zealand
- Lobster from South Africa, Indonesia, Mexico, the USA and Canada.

There is a general understanding that Southern Rocklobster is the premium product being a large cold water lobster. It is said to have taste and texture advantages. Western Rocklobster is regarded as a premium product but not at the level of southern rock. It is treated as a warmer water product with taste and size advantages compared to the range for other smaller lobster available from countries like South Africa, Indonesia and Mexico and the plentiful "Boston" lobster from the US.

An important consideration is whether these various lobster products fit into niche markets with very little substitution between them of whether they are substitutes.

If they are not regarded as substitutes then each can follow an independent pricing policy in the target markets. In particular, an increase in the price of one will not switch demand toward the others and will not therefore trigger an increase in the market prices for these products.

In determining the approach to take to price in the simulation modelling, the important question is the extent to which the various lobster species can be regarded as close substitutes. In particular, can they be modelled as close substitutes in the in the Hong Kong/China market, considering that the model works on an annual basis over many years.

If they could be regarded as close substitutes, then an increase in the price of one will cause a switch in demand to the others as substitutes and will trigger an increase in their price. We can think of there being an equilibrium price structure encompassing relative prices that reflects the various quality attributes of the lobster. For example, live Southern Rocklobster can command a premium as a cold water lobster over Western Rocklobster or lobster from South African or the USA (Maine lobster).

In this case, a price shock in one product will be transmitted to the others and their equilibrium relative prices will be restored. In this case, the price of a single lobster species cannot be independently increased through strategies such as withholding supply in the long run because such a shock will transmit increased demand elsewhere and will generate supply response elsewhere. Obtaining a price increase relative to other competing or substitutes species requires that purchasers shift their preferences in favour of the particular species such that they perceive a an increase in its relative price as worth paying. Such an outcome may result from a simple change of preferences, a change in the product itself or potentially advertising that improves the consumers' view/perception of the product ad their willingness to pay for it.[25]

Where product are close substitutes we can set a price for a single product and assume that it will be maintained relative to others growing only at whatever the forecast growth in equilibrium market price is over time. That is it will maintain its relativity.[26]

Testing Price relationships

Western Rocklobster is now primarily exported as live product to China, including Hong Kong SAR.

In these export markets it competes with rock lobster that are close to it in character, primarily Southern Rocklobster sourced from New Zealand and Australia, primarily South Australia. However, there are major exports of lobster of other species and from other jurisdictions. Closer to home, tropical rock lobster is exported from Queensland and NSW. Major suppliers also include South Africa, Mexico and North America.

Clearly, these products are substitutes. If they were perfect substitutes, they would sell at exactly the same transport and exchange rate adjusted prices.[27] If they were imperfect substitutes they

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[25] For some products, an exclusivity argument may be used. By combining promotion with limited supply, buyers may be convinced that they are securing an exclusive product and be willing to a pay a premium for it.

[26] In the short run when other supplies have limited ability to change supply or switch markets, a reduction in supply for one species may increase its price relative to other products. How long such a premium can be sustained depends on how the consumers view the product in relation to its substitute's and how competing suppliers respond. If no fundamental change in preferences is achieved, eventually we expect the price relativities to be restored.

[27] That is a strict law of one price model would hold.

would not sell at equivalent adjusted prices bur arguably there would be a set of price relativities between them that would reflect their position in the market place. Over time, the overall price level for lobster would increase or decrease as exogenous variables impact the market. An example would be the GFC, which shifted the demand for lobster to the left and affected all lobster suppliers.

However, in both the case of perfect substitutes and close but imperfect substitutes, specific product/region shocks can occur which effect one supplier/region independently of others. An example might be a contraction of harvest because of a biomass decline, an increase in harvest because of biomass recovery or bad weather that substantially affects the harvest.

If a product had no substitutes then these product specific volume impacts would show up as changes in price that would be sustained until such time as they are rectified for the individual product concerned.

If the product has substitutes then these product specific shocks should trigger adjustments that involve both the product of interest and the substitutes. For example, a shortage of supply in one product could be expected to trigger price rises for that product along with a tendency for some customers to shift to substitutes and for competing suppliers to increase supplies.

If there is an underlying price relationship between the products that constitutes the long run equilibrium then these adjustments will bring this back into operation over a period. For example if two products are substitutes and one experiences a price shock increase the expectation is that there will be pressure for this price to come back down and for substitute product prices to increase toward re-establishing the price relativity. Whether this is at the initial price level will depend on the nature of the initial shock and the speed with which the price responses occur will depend on the underlying attributes of the market.

If two price series across similar products (southern and Western Rocklobster) sourced from different locations (New Zealand, Western Australia) can be said to be integrated if there exists a long-term equilibrium relationship between them.

The degree of transmission of price signals between these two markets could potentially be obtained by fitting a classical regression model as follows:

$$Y_t = \alpha + \beta X_t + \varepsilon_t$$

Where
Y_t = price in market 1, the dependent price
X_t = price in market 2, the independent price.
α and β are estimated coefficients
ε_t = error-term.

For the classical regression model to be valid in this case. it is required that the y and X variables used in the regression be stationary and that the errors have a zero mean and finite variance.

Where the data on prices are time series, it is possible that each series is non stationary. A stationary series is one whose parameters (mean, variance and autocorrelations) are independent of time. A non stationary series does not satisfy this requirement. Regression between two non stationary variables may result in spurious relationships being considered meaningful with a high $R^{2.}$ and t-statistics that appear to be significant, but the results have no economic meaning.

This being the case the standard practice is to check the time series variables for stationarity. Typically, this is done using an Augmented Dickey Fuller test. If the on stationary series are stationary when first differenced then they are said to be integrated of the order one or I (1), if stationary at the second difference they are integrated at order two or I (2).

If two series are non-stationary but integrated of the same order, the validity of the above regression approach needs to be verified by testing to determine if the series are cointegrated. This can be done using the standard Engle Granger or Johansen tests. For example, Engle and Granger (1987) demonstrated that, if the residuals from that standard regression shown above turn out to be stationary when the variables are non stationary in the levels, then the series are co-integrated and there exists a long-run relationship between the two series.

Two I(1) time series (X_t and Y_t) are cointegrated if there is some linear combination that is stationary. This would take the form;

$$Z_t = Y_t - \beta X_t$$

Where Z is the portion of (levels of) Y that are not shared with X, the equilibrium errors.

This equation can be written;

$$Y_t = \beta X_t + Z_t$$

Where the cointegrating vector – Z_t can be estimated by regressing Y_t on X_t.

In the above equation, Z represents the portion of Y (in levels) that is not attributable to X. In essence, this means that Z captures the error correction relationship by capturing the degree to which Y and X are out of equilibrium. Z captures any shock to either Y or X and if Y and X are cointegrated, then the relationship between the two will adjust accordingly.

Shocks to X have an impact on Y. We can think of two effects on ΔY. A part of the shock to X might immediately affect Y in the next time period. This means that ΔY reacts to $\Delta X_{t-1.}$ A part of the shock may also disturb the equilibrium between Y and X, sending Y on a period of long term adjustment to a value that reproduces the equilibrium state between the two such that the final value for Y is consistent with an equilibrium between Y and the new post shock value of X.

The effect of this is that ΔY_t is a function of both ΔX_{t-1} and the extent to which the two variables were out of equilibrium in the previous time period.

For example, if the price of Western Rocklobster in Hong Kong (Y) and Southern Rocklobster in Hong Kong (X) are cointegrated and a shock occurs that changes the price of Southern Rocklobster (ΔX_{t-1}), then we would expect to see a short term impact on Western Rocklobster prices (ΔY_t). Following this, we expect a longer adjustment period over which the underlying equilibrium relationship is re-established, ceteris paribus. This might mean, for example, that with monthly price data an initial shorter term reaction occurs in the subsequent month but several months may be required to achieve the new equilibrium value for Western Rocklobster.

If the variables are integrated at the same level (e.g. I(1)) and determined to be cointegrated with one or more cointegrating vectors, then the appropriate estimation technique to use to test the relationship between them is the vector error correction model (VECM).

Implementation of the VECM involves two discrete steps. First regress Y on X to obtain an estimate of Z. Second regress ΔY_t on Z_{t-1} and any relevant exogenous variables.

The first step is the regression;

$$Y_t = \alpha + \beta X_t + Z_t$$

The cointegrating vector is measured from this estimated regression as;

$$Z_t = Y_t - \beta X_t - \alpha$$

In step 2 the estimated error can be used in a regression to explain ΔY_t as shown below.

$$\Delta Y_t = \beta_0 \Delta X_{t-1} - \beta_1 Z_{t-1}$$

Z_{t-1} is the error correction component EC_{t-1}. In the above error correction model, β_0 captures the short term effects of a change in X in the prior period on Y in the current period. β_1 captures the rate at which the Y adjusts to the equilibrium state after a shock to X. It captures the speed of error correction.

The following analysis investigates lobster export prices to determine if an underlying long run relationship exists between them.

First, we assess whether a set of prices move "move together" in the sense that there is a relationship between them that constitutes a long run equilibrium. This is the test for cointegration. Second, if the prices are cointegrated, we consider how a shock in one price transmits to the others. This is an application of vector error correction (VECM) model.[28]

Insofar as applying this model to lobster is concerned, we can consider two approaches. First, we can look at what we consider the closest set of substitutes to test if different species of rock lobster from different origins "move together'. Candidate data for this would be live lobster export volume and value data from the ABS and NZ Statistics. This data can be obtained monthly over an extended period and is on a consistent basis. Second, we could consider country specific data from Commtrade. This allows a consideration of lobster prices for lobster from various countries. It has the disadvantage that the data is not available for all relevant countries and it is difficult to separate live exports. The monthly Commtrade data is also limited to post 2009.

The analysis below uses the Australian and New Zealand monthly data on live lobster exports from each state of Australia and from NZ to the major common market for these exports Hong Kong SAR for the period Jan 2000 to December 2011.

A Johansson cointegration test is applied using the monthly export price data. Fundamentally, cointegration tests whether a suite of time series have a stable relationship to each other which constitutes a long run equilibrium. If cointegration is present, there will exist a stable long-run relationship among the non-stationary price variables. Cointegration implies the existence of price parity and that the products being evaluated belong to the same market. This does not mean that prices are always equal or bear the same relativity. Prices may drift apart in the short run due to

[28] These models were specifically developed to apply to cointegrated data. If the data is proved not to be cointegrated we could use vector auto-regression (VAR) models.

random shocks or because of sticky prices and contract conditions but in the long run adjustments on both the demand and supply side will tend to send prices back to their equilibrium path.

The price data is shown in Figure 23. During 2010-2011, there was in place an export ban on lobster from Australia to China. At this time, the market was arguably not fully functional. Prices have trended up in the latter part of the period.

Cointegration analysis is relevant when multiple time series are thought to be related. In this case, lobster export prices[29]. One price series cannot be cointegrated. Consider the price data in Figure 23 as a set of integrated price variables. Each price denoted *P,l,o* (price of lobster, *l*, from a given source, *o*) is I(1), but follows a common long-run path, Cointegration between the export prices could reflect the idea that in the long run there is a stable price differential between them, that price differentials between any two origins were stationary. In testing for cointegration, nothing is being said about the direction of causality. That would require a specific model to be tested where one variable or more could be specified as independent variables.

In this case, we treat the prices such that none of the origins is more important than any other and all prices are 'adjusting' prices. The Johansen test for cointegration was applied to the price data in Figure 23 under two scenarios. The first used data from the period until September 2010 because the data after this point was affected by the lobster trade ban. The test was also run with all data include to test if the ban affected period influenced the results.

Graphically the prices tend to move together but have minimal trend. Application of the cointegration test of fitting a cointegrating VEC model starts with determining the appropriate number of lags to include. With all prices included, a test of lag structure suggests that a lag of three is appropriate.

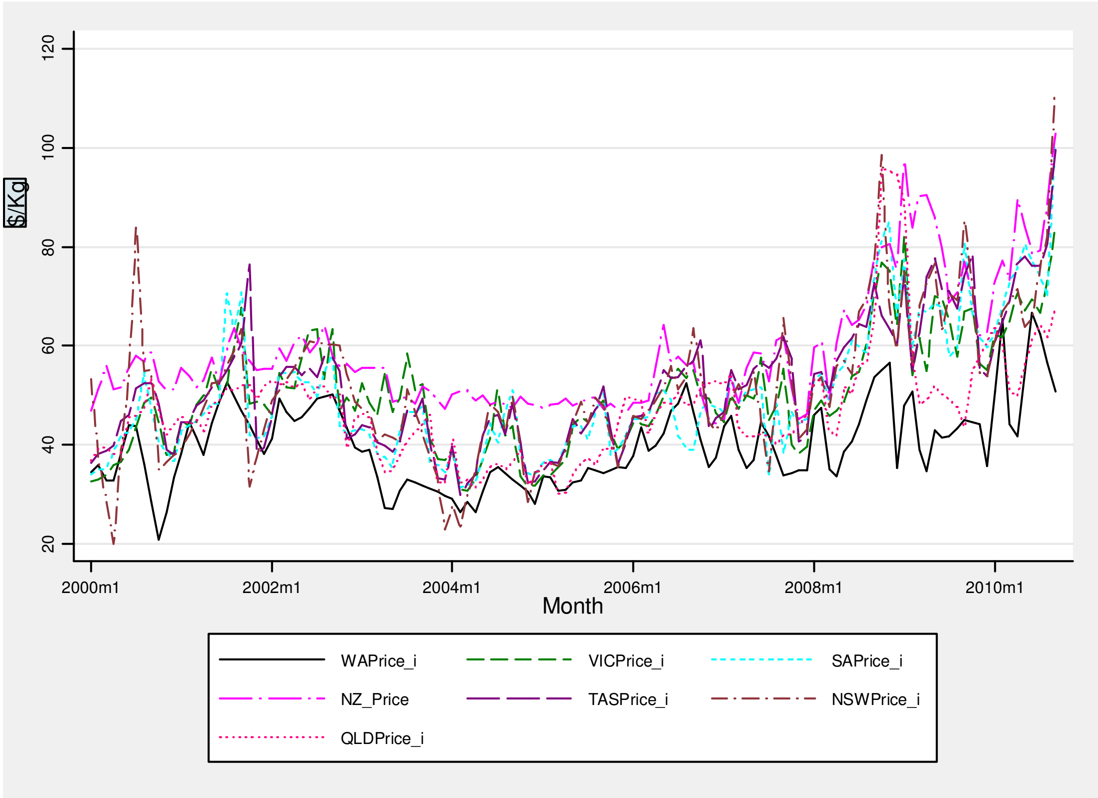
The price data in Figure 23 indicates that while the series do appear to move together, the relationship is not that simple. There are periods when prices appear to diverge with, for example, the New Zealand price being above the rest and the WA price tracks lower in recent years.

Each of the price variables was tested for stationarity using the Augmented Dickey-Fuller Test. Stationarity was rejected in the levels but each was stationary with first differencing.

These results are shown in Table 7. The null hypothesis of non stationarity in the levels cannot be rejected at the 1% level but can be rejected at the 15 level for the first differences. The subsequent analysis is based on all prices being I(1).

[29] As a practical matter, time series procedures are less demanding in terms of data requiring only information on prices and not information on the full set of variables commonly used in demand studies (i.e., quantity, income, etc.)

Figure 23: Live Lobster Export Prices to Hong Kong SAR, January 2000 to December 2011.



Source: ABS International Trade: Customized Table and NZ Harmonized Trade Exports

Table 7: Tests for Non Stationarity in Export Prices to Hong Kong SAR.

Lobster Price	ADF in Levels	ADF in Fist Difference	1% Critical Value	5% Critical Value
NZ Price	-1.031	-6.885	-3.498	-2.887
WA Price	-2.732	-8.514		
SA Price	-1.599	-7.878		
VIC Price	-2.681	-7.098		
TAS Price	-2.335	-6.980		
NSW Price	-.575	-4.957		
QLD Price	-2.825	-5.893		

The results of applying the Johansen test for cointegration to these price variables are shown in Table 8. Both the Trace test and the Maximum Eigenvalue test for the number of significant vectors are reported. The Trace test is a likelihood ratio test for at most r cointegrating vectors. The Maximum Eigenvalue test is a test of the null hypothesis of r+1 cointegrating vectors against the alternative hypothesis of r cointegrating vectors.

Table 8: Johansen Test for Cointegration; Export Prices to Hong Kong SAR.

Johansen tests for cointegration

Trend: constant — Number of obs = 141

Sample: 2000m4 - 2011m12 — Lags = 3

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	105	-3013.8212	.	262.3077	124.24
1	118	-2967.9352	0.47841	170.5357	94.15
2	129	-2933.8181	0.38364	102.3016	68.52
3	138	-2916.012	0.22320	66.6893	47.21
4	145	-2902.3973	0.17561	39.4599	29.68
5	150	-2891.0987	0.14808	16.8628	15.41
6	153	-2883.672	0.09998	2.0094*	3.76
7	154	-2882.6673	0.01415		

maximum rank	parms	LL	eigenvalue	max statistic	5% critical value
0	105	-3013.8212	.	91.7720	45.28
1	118	-2967.9352	0.47841	68.2342	39.37
2	129	-2933.8181	0.38364	35.6123	33.46
3	138	-2916.012	0.22320	27.2294	27.07
4	145	-2902.3973	0.17561	22.5971	20.97
5	150	-2891.0987	0.14808	14.8534	14.07
6	153	-2883.672	0.09998	2.0094	3.76
7	154	-2882.6673	0.01415		

The hypothesis of no cointegration (0 rank) can be rejected at the 1% level. Six cointegrating equations exist if all seven prices are included. It should be noted that that there is no causality being tested at this point, all prices are jointly endogenous. The finding that there are 6 or n-1 cointegrating equations suggest that there is one cointegrating factor and this implies market integration.

Interpreting results with from six cointegration equations when all seven of the price variables are included in a VECM is complicated. Fortunately, bivariate analysis will suffice. The bi-variate analysis contains the same information as multivariate analysis. The above results indicate that the seven price system is cointegrated with n-1=6 cointegration vectors.

Stock and Watson (1988) show that if all variables in a system are pair wise cointegrated, then the multivariate system contains only one stochastic trend and a multivariate system with n variables and one stochastic trend, has n-1 cointegration vectors.[30] Bilateral cointegration tests of fish markets have been used to test for market integration in European whitefish markets ((Asche et

[30] Johansen and Juselius (1994) show that an exactly identified representation of the system can be defined using bi-variate relationships.

al. 2002) and (Nielsen et al. 2009) Spanish hake markets (Garza-Gil et al. 2001), the Philippines (Garcia & Salayo 2009) and India (Shinoj et al. 2008).

Following on from this literature, we look at the key bilateral relationships- WA versus NZ prices, WA versus SA prices and SA versus NZ prices. Each is tested for cointegration. The adjustment parameters are estimated along with impulse functions. Using a modified approach based on Giles, Granger causality is also reported.

Table 9 presents the cointegration analysis for the bivariate price relationships of particular interest.

The null hypotheses of no cointegration can be rejected at the 1% level for each case. Johansen's testing procedure starts with the test for zero cointegrating equations (a maximum rank of zero) and then accepts the first null hypothesis that is not rejected. In the output below, we strongly reject the null hypothesis of no cointegration and fail to reject the null hypothesis of at most one cointegrating equation. Hence, we accept the null hypothesis that there is one cointegrating equation in the bivariate model for each of the bivariate price relationships included. In essence, this confirms for the important bivariate relationships what has already been determined in Table 8.

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Table 9: Johansen tests of cointegration for bivariate price relationships

WA Price to NZ Price	Obs=142	Lag=2	Trend=constant
Rank	Eigen Value	Trace Statistic	1% Critical Value
0	-	51.4656	20.04
1	.28110	4.6001*	6.65
2	.03188		
SA Price to NZ Price	Obs=142	Lag=2	Trend=constant
Rank	Eigen Value	Trace Statistic	1% Critical Value
0	-	37.291	20.04
1	.20944	3.9208*	6.65
2	.02723		
WA Price to SA Price	Obs=142	Lag=2	Trend=constant
Rank	Eigen Value	Trace Statistic	1% Critical Value
0	-	53.5541	20.04
1	.28292	6.3297*	6.65
2	.04360		

Model Structure for Western Rocklobster

We have defined the internal governance structure to be the structure of decisions across all of the private interactions in the chain. External governance relates to the role of Government in setting up and operating within the existing management model.

The recent literature focusses on governance across the whole supply chain and the way that the mix of private and public governance mechanisms interact to determine the overall value and performance of the fishery.[31]

One way to put some quantitative dimensions to these governance issues is to build a supply chain model for a fishery that can be used to simulate various changes in the array of rules and policies that already exist within the management system, and to simulate new possibilities that currently are not within the management structure.

When applying this to any particular fishery the exact configuration will be determined by the structure of the fishery, but it should be capable of considering changes to the structure.

Supply Chain Concepts Applied to Western Rocklobster

Figure 24 shows a schematic for Western Rocklobster. Government sets the fisheries management regime encompassing licensing, harvest quota and harvest and gear rules. These interact with the biomass to produce a harvest outcome via decisions taken by fishers about the number and timing of fishing days, effort measured as pot lifts and use of capital and labour.

The processors receive the catch and pay beach prices. By offering particular beach prices for catch delivered, they can influence the pattern of catch on a daily and monthly basis. The margins they make depend on the balance between the beach price they pay and the reselling price they receive when selling to buyers.

The wholesalers pay the processor and then proceed to market the product by on selling to various retail customers. Their margin is a function of the price they sell at, the price they pay the processor and their distribution and marketing costs. For the live rock lobster market, these wholesalers are mainly in Hong Kong and China and lobster is airfreighted to them. They either distribute straight from the airport to customers or take the product to their shops where they hold it in tanks until they are able to sell and deliver it to customers. Margins are smaller for the former route than the latter because the former avoids holding costs for the wholesaler.

A preliminary model that captures aspects the most important of the above schema has been developed[32] for the Western Rocklobster fishery. It has been determined that this is the best one to do first because of its single species status. This will allow the basic logic to be evaluated and refined before moving to the finfish fishery where the model will have to deal with multiple species, and different and in some ways less specific sets of harvest rules as well as local marketing, as opposed to global market issues.

The purpose of the model developed for Western Rocklobster is to examine how selected governance issues affect the overall economics of the Western Rocklobster supply chain

The focus is on making the model as useful as possible. Therefore, it was built around the fewest and simplest assumptions possible for the model to be fit for purpose, which is to examine how selected governance issues affect the overall economics of the Western Rocklobster supply chain.

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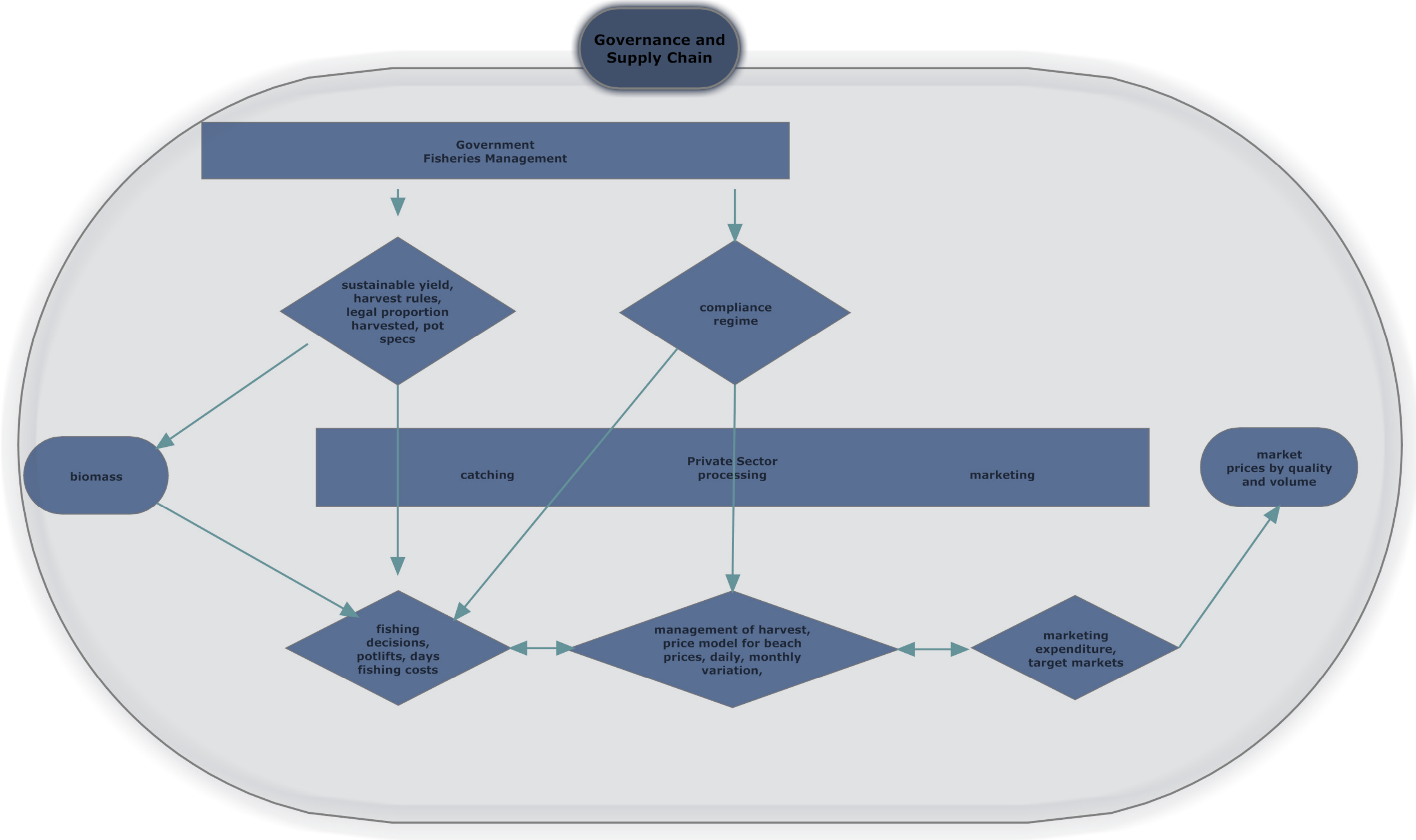
[31] Often the rationale has been to determine how the overall surplus gets distributed across the chain. Less focus has been put on the analysis of specific management decisions. See

[32] A version of the original model was presented to seminars at the Department of Fisheries. The revised version to allow for the December 2013 control rules was presented at a seminar at the Geraldton Fishermen's Cooperative.

Figure 24: A Schematic Supply Chain for Western Rocklobster



The WRLF Supply Chain Bio-economic Model

We have defined the internal governance structure to be the structure of decisions across all of the private interactions in the chain. External governance relates to the role of Government in setting up and operating within the existing management model.

The recent literature focusses on governance across the whole supply chain, and the way that the mix of private and public governance mechanisms interact to determine the overall value and performance of the fishery.[33]

One way to put some quantitative dimensions to these governance issues is to build a supply chain model for a fishery that can be used to simulate the impact of various changes in the array of rules and policies that already exist within the management system, and to simulate new possibilities that currently are not within the management structure.

When applying this to any particular fishery the exact configuration will be determined by the structure of the fishery, but it should be capable of considering changes to the structure.

As noted above, is it is expected that the harvest strategy for the Western Rocklobster Managed Fishery, that comprises a set of decision control rules for annually setting the Total Allowable Commercial Catch (TACC), will be finalized later in 2014.

To enable some of the governance issues embedded in the proposed Harvest Strategy to be explored, a bio-economic simulation model of the Western Rocklobster fishery was constructed as part of this project. Because this model was constructed in 2012, it incorporates the essence of the TACC setting control rules as envisaged in Fisheries Management Paper No. 254, but only some of the possible refinements proposed in Fisheries Management Paper No. 263.

Specifically, the model was designed to investigate the impact on economic returns in the WRLF supply chain of alternative specifications of decision control rules for TACC setting embedded in the HSCR. The analysis of supply chain economics must start with a consideration of the population dynamics in the WRLF. The fishery is subject to substantial year-to-year fluctuations in recruitment, as well as quite high levels of exploitation of available legal biomass in each fishing season, and non-trivial levels of growth and natural mortality of recruits and survivors until harvested. Hence, the evaluation of the operation of alternative specifications of the TACC setting control rules needs to be simulated over a period of several decades.

At its simplest, stable harvesting inputs mean variable catches given fluctuations in biomass. This then translates into consequences for the processing and marketing sectors because the outputs from harvesting are inputs to processing. If a set of harvest rules involves stable catching inputs, and variable catching outputs, the processing sector has to deal with varying supply inputs. As a result, maintained processing capacity will need to be higher, and processing capacity utilisation will be lower. The processing sector will have different costs depending on the variability of the catches delivered to it. This will also influence the nature of further processing and promotion in target markets. [34]

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[33] Often the rationale has been to determine how the overall surplus gets distributed across the chain. Less focus has been put on the analysis of specific management decisions. See

[34] For example when Western Rocklobster were caught in a short season from October to March, overseas markets effectively could not promote them to customers for five months of the year.

The markets into which products are sold will react differently to fluctuating versus stable supply. If the processor has to market fluctuating output reflecting the fluctuating catch levels, this will potentially affect average prices received. If higher average prices would be received by delivering stable outputs to market, processors must make decisions as to the best way to store and process product. This has implications for the capital costs of running the business. Alternatively, they must make beach pricing decisions that transmit incentives for stable catches. This will then affect the variability of catching sector inputs and associated catching costs.

Prices received by processors, and derived prices paid by processors to fishers, will interact with harvest rules to determine the overall economic performance in the supply chain when fluctuations in harvest levels influence prices received from the market.

Through these linkages, decisions made about aggregate harvest levels, specific harvest rules, beach price structures and marketing effort will all influence overall economic performance. These linkages need to be consistent and reinforce each other if the desired outcomes are to be successfully achieved.

Harvest strategy and control rules (HSCR)

Since the move to ITQs and the coincident reduction in harvest based on a decline in biomass and available stock, the industry has put considerable effort into developing specific harvest strategies. These strategies were first set out in Fisheries Management Paper 254 (2012). These rules were built into the original formulation of the supply chain model. In December 2013, the Department of Fisheries proposed revisions to the harvest rules in Fisheries Management Paper 263 (2013). The mode has been revised to take account of this newer version of the proposed control rules.

The current harvest strategy requires management of fish stocks to have explicit objectives that reflect scientific knowledge and community values. It is based on developing a clear articulation of how acceptable performance against the objectives will be determined, measured and achieved. A key element is that the management rules attempt to optimise community benefits based on managing fisheries to an appropriate target level, rather than just ensuring they remain above a specified threshold level.

The harvest strategy incorporates indicators to measure performance against objectives, reference values for indicators that describe acceptable and unacceptable performance, a target biomass value that optimises the fishery's economic performance, and a range of predefined decision rules to determine management actions that avoid unacceptable performance and reach target levels.

For Western Rocklobster, two key objectives underpin the HSCR framework. The Sustainability Objective is the primary objective of the HSCR, and must be met irrespective of other objectives in the HSCR. A second, and secondary objective, is designated the Harvest Objective.

Proposed Sustainability Objective

The sustainability objective as stated in FMP No. 263 is:

"To ensure that the egg production in Breeding Stock Management Areas of the fishery …. remains above its threshold value for the next five years with a probability greater than 75%"

The "threshold values" referred to in this objective are based on levels of egg production capacity observed prior to the increase in fishing effort and efficiency through technology uptake that occurred in most parts of the fishery around the mid-1980s. Detailed rules for achieving sustainability are based on target indicators. In essence, an upper bound to total allowable commercial catch (TACC) is set to ensure that the sustainability objective of maintaining acceptable egg production levels in each Breeding Stock Management Area (BSMA) is met.

To ensure long term sustainability, the egg production indicator value (EPIV) is projected out five years into the future. It takes into account both puerulus settlement and future catch setting arrangements. Should modelling indicate that the threshold level in any one of the BSMAs may be breached within the five year projected time period, management action would be required to ensure that there is no breach of the threshold level. This would include a reduction in TACC for the relevant zone(s), or a change in biological controls.

A prediction that EPIV would breach the threshold in the short term (one or two years) would trigger an immediate cut to next year's TACC, if necessary by more than 20%. A prediction that EPIV would breach the threshold in the longer term (four or five years) would still trigger a response, but cuts to subsequent TACCs might be less immediate , and/or less drastic (e.g. < 20%).

Proposed Harvest Objective

The proposed second, and secondary objective, is designated the Harvest Objective in FMP Nos. 254 & 263. Specifically, it has been recommended that the following proposed Harvest Objective be incorporated into the Harvest Strategy:

"Once the Sustainability Objective has been satisfied, TACCs set for the fishery should use Maximum Economic Yield to determine an optimal range of legal proportion harvested that would optimise the economic value of the fishery by increasing stock abundance and catch rates and thereby providing high economic returns and greater amenity to the fishery and the WA community."

The Legal Proportion Harvested (LPH) is measured as Catch /Total Legal Biomass (LB). The value of this parameter can be selected with the aim of ensuring relatively high catch rates and higher economic returns by way of lower catching costs. The management regime will adjust upcoming year's TACC plus indicative TACCs for four future years' set so as to optimise the likelihood that LPH stays within the target range (i.e. within ± 5%).

In the event that the egg production is below, or predicted to fall below the threshold levels in one or more of the BSMA's, then the LPH for those zones would be reduced until the Sustainability Objective is met. In this instance, the Harvest Objective would not be used for determining TACCs for the affected Zone(s).

This proposed Harvest Objective is based on a belief that reducing the allowable catch below the limit provided for by the Sustainability Objective, and below Maximum Sustainable Yield (MSY), would yield an economic benefit. Thus, the aim of a Harvest Objective is to establish an allowable catch limit more consistent with Maximum Economic Yield (MEY) than with MSY, and to maintain it within a target range that will enable the fishery to be managed in a way that achieves benefits of importance to stakeholders.

The main reason to have a catch limit that is set by the Harvest Objective is to produce good catch rates and high profitability for the fishery, while at the same time protecting the breeding stocks. If the LPH is relatively low, more lobsters are left in the water each year and hence their abundance increases together with the abundance of the breeding stock. A high abundance of lobsters results in higher catch rates, which allows industry to catch their quota with less effort. By comparison, a high LPH usually results in fewer lobsters being left in the water at the end of the year and hence the abundance declines, including the abundance of the breeding stock. A low abundance of lobsters results in lower catch rates and results in both sectors being able to take their allocation more efficiently.

Various means of achieving this objective were still being discussed at the time of writing this report. However, most of the discussion has focused on the notion that the TACC would be set at a conservative level in order to limit the Legal Proportion Harvested (LPH) to some maximum proportion, and thereby increase lobster abundance and build catch rates to a target level to reduce catching costs, and increase economic returns.

In conjunction with the operation of LPH, the management rules attempt to ensure that the change in TACC between years is less than 20%. While the “optimal” LPH may vary over time due to fluctuations in lobster abundance, lobster prices, and fishing costs, the intent is not to vary the target LPH from year to year.

Other considerations

Also under consideration are a range of related issues, such as whether "legal lobsters" include, or do not include undersize lobsters that become legal (by moulting) during the season, and whether "legal lobsters" should include oversize, setose, tarspot or berried females. It is anticipated that such issues will be finalized prior to adoption of the Harvest Strategy, and once resolved are unlikely to be changed for the foreseeable future.

Hence, the key governance questions involved in the introduction of the Harvest Strategy are the actual levels of the following two key parameters that will govern TACC setting in future years:

- the threshold value for egg production in each of the fishery’s BSMA's
- the limit on Legal Proportion Harvested

Model Elements

The model developed is based on the above harvest rules to capture the new management regime. The focus in building the model was on making it as useful as possible. Of necessity, this involved simulating the impact of TACC setting rules in the HSCR on population dynamics in the fishery given variable recruitment patterns spanning several decades. It therefore was built around the fewest and simplest assumptions possible for the model to be fit for purpose.

Embedded within it are the following initial key assumptions. Predominantly these reflect the discussions with industry representatives and managers. The model is based on a simple supply chain comprising a catching sector and a processing/marketing sector. Both market and harvest strategy governance issues are built into the model.

The novel focus in the model is on the link between the catching and processing/marketing sectors, namely price. Beach price is the output price for the fishers but the input price for the processors. It determines revenue for the fishers and input cost for the processors.

The end price in the WRL supply chain is set by competitive export markets.[35] The harvest related governance issues in the model are those within the current harvest strategy and incorporate decision rules for the commercial catching sector of the Western Rocklobster fishery.

The annual scale of processing operations in the model is determined by annual catch size. This can vary year on year, and is determined by the TACC setting control rules in the Harvest Strategy.

With respect to costs, catch volume delivered/received is the key input for the P&M sector, and dominates variable costs. Most other costs also vary proportionally with catch size. The key determinant of fixed costs is capacity to process maximum potential catch size. Supply of processing/marketing inputs is assumed to be highly elastic. [36]

Western Rocklobster exports are a small proportion of world trade in all types of lobsters, which are close, albeit not perfect substitutes. Consequently, long run final demand is assumed to be very elastic, as is the long run derived demand for landed catch. However, in the short run, demand may be inelastic.

Prices paid to the fishers for Western Rocklobster are set equal to final wholesale market price less the estimated processing/marketing margin. This equates to beach price. Total processing/marketing profit is set equal to annual catch size times the assumed processing/marketing margin less fixed costs.

Insofar as fishing behaviour is concerned, the number of pot lifts is the key measure of effort, and this determines fishing variable costs. The annual total allowable commercial catch (TACC) and legal biomass (LB) are the key influence on required pot lifts (PL).

The supply of pot lifts (PL) is assumed to be elastic up to the capacity limit set by long run investment in boats and other fixed equipment that determines capacity and fixed catching costs. Variable catching costs are a function of catch size. They increase with catch size because:

- catchability varies during the fishing season
- average cost of a fishing trip varies from month to month

Total aggregate catching sector profit is measured as the set TACC times the catching margin less catching fixed costs Intra year, catching margin is inversely related to TACC while the inter year, catching margin is inversely related to LB.

Model Specification

The model comprises four conceptually distinct components in, these being:

- A simple simulation of population dynamics which allows simulation of the impact of highly stochastic annual recruitment and chosen annual TACC on annual closing legal biomass (CLB)
- Harvest strategy decision rules based on alternative scenarios for TV (CLB) and Alternative scenarios for LPH

[35] This does not mean a single rock lobster or lobster price per kg but a set of relative prices for lobster of various species and grades. The exact shape of the demand curve will be determined when feedback from wholesalers in Hong Kong and China is received.

[36] Preliminary feedback from wholesalers in Hong Kong confirms that this is the case for their operations.

- Catching sector economics which uses an economic model of a fishing operation to estimate economic impact of HSCR on the catching sector
- P&M sector economics which uses an indicative cost and margin structure to estimate economic impact of HSCR on the P&M sector

The model has a number of necessary simplifications; including the following:

- It is an annual model – the only variation is in inter-year variables such as catch
- It is a single zone model of the entire fishery
- There is no recreational fishing sector
- The functional form of key relationships in the integrated simulation of population dynamics was estimated from selected outputs from the Department of Fisheries biological model of WRLF model. Due to the degree of simplification involved, these estimates are only "ball park" precise.
- Annual recruitment is based on one plausible 46 year time series of PSI that mimics the pattern of variability in average PSI since commencement of this index[37].
- Simplified decision rules are built into the model for setting TACC that retain the essence of the HSCR.

The population dynamics are simulated by the following model.

- $ALB_t = OLB_t + R_t + G_t - M_t$
- $CLB_t = ALB_t - TACC_t$
- $OLB_t = CLB_{t-1}$ where:
    - OLB_t = Opening legal biomass in year t
    - ALB_t = Available legal biomass in year t
    - R_t = Recruits to legal biomass in year t from pool of sub-legal juveniles = a function of PSI in t-3 & t-4
    - G_t = Growth of "survivors" in year t (depend on LPH)
    - M_t = Natural mortality in year t (depend on ALB_t)
    - $TACC_t$ = Total allowable commercial catch in year t
    - CLB_t = Closing legal biomass in year t

The sustainability decision rules are represented in the model to ensure that the CLB remains above the TV for next 4 years by applying the following control rules:

- Initial provisional $TACC_0 = ALB_0 * LPH$
- projected CLB_0 = = ALB_0 – initial provisional $TACC_0$
- IF projected $CLB_0 < TV$, set indicative $TACC_0$ so $CLB_0 = TV$
- IF projected $CLB_1 < TV$, set indicative $TACC_0$ so $CLB_1 = TV$
- IF projected $CLB_2 < TV$, set indicative $TACC_0$ so $CLB_2 = TV$

37 Ex ante,, the time series of future PSI and future annual recruitment is unknowable, and conceivably could take any one of an infinite number of alternative paths. It was not feasible to explore exhaustively the extent to which the impact of control rules on TACC is sensitive to all possible differences in the future time sequence of PSI and recruitment. The sensitivity was investigated across four alternate plausible year time series that mimic the past pattern of variability in PSI. The results are reported later in this report.

- IF projected $CLB_3 < TV$, set indicative $TACC_0$ so $CLB_3 = TV$
- declared Year 0 $TACC_0$ = lesser of:
    - minimum indicative $TACC_0$
    - provisional $TACC_0$

These are recursive relationships that had to be solved iteratively over hypothetical 46 year period

Findings

Implications of Harvest Rules for the TACC and CLB

Key questions regarding the impact of these control rules are:

If a conservative/precautionary approach is taken to the biomass by setting TV = 15,000;

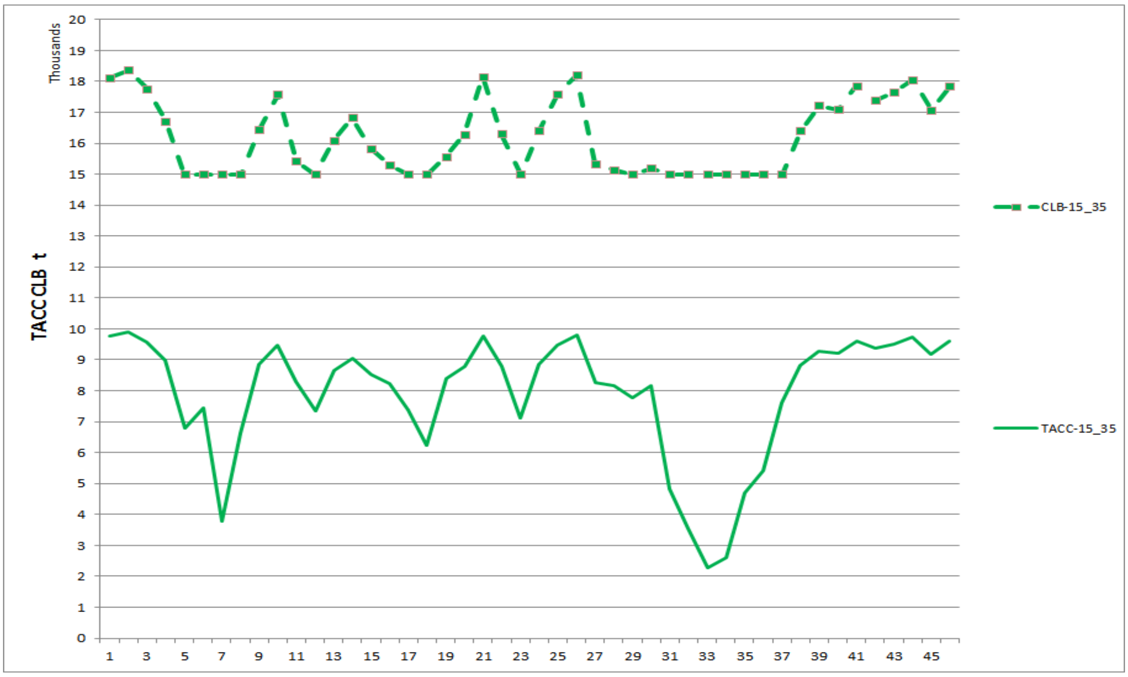
- How much will TACC vary between years?
- Will floor for CLB be breached?
- What will be impact of setting LPH = 35% vs 55%

If a more exploitative approach is taken to the biomass by setting TV = 5,000;

- How much will TACC change between years?
- Will floor for CLB be breached?
- What will be impact of setting LPH = 35% vs 55%

Figure 25shows the effect of a precautionary approach that sets the floor TV at a high value of 15,000t, while setting the LPH at a modest value of 35%. For this scenario, while average TACC = 7,902t, in one year the TACC had to go low as 2,285t to stop the CLB falling below the floor TV = 15,000t. At the other extreme, the maximum TACC over the 46 year period was 9,888t. This means that the P&M sector needs peak capacity to process 9,888t.

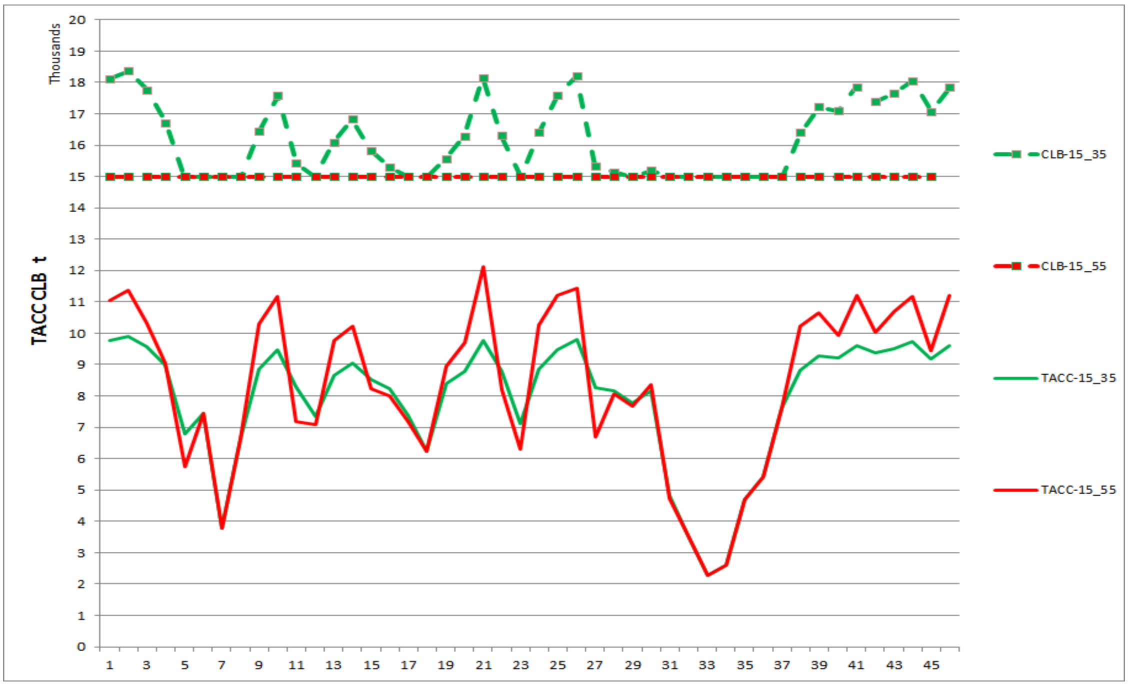
Figure 25: TACC and CLB for TV = 15,000; LPH = 35%;



Note that while the control rules prevent CLB falling below the floor TV of 15,000t, the modest LPH value of 35% ensures that CLB is greater than 15,000t in many years. As a result, average CLB = 16,201t over the simulated time period of 46 years.

Figure 26 shows a comparison of the impact on TACC and CLB of alternative LPH settings of 35% and 55% when a precautionary TV value of 15,000t is chosen.

Figure 26: TACC and CLB for TV = 15,000; LPH = 35%; 55%



With the LPH set at 55%, average TACC is 8,373t, which is significantly lower than the average TACC of 7,902t if LPH was set at 35%. Nevertheless, for both LPH =35% and LPH =55%; the minimum TACC required to stop CLB falling below floor TV of 15,000t is the same at 2,285t. On the other hand, when LPH is set at 55%, the peak annual TACC is 12,125t, which means that the P&M sector needs to invest more heavily in a greater peak capacity to process the 12,125t, which is significantly above the peak production of 9,888t if LPH was set more conservatively at 35%.

The impact of alternative LPH values on CLB is more marked. In contrast to the case when LPH was set at the modest value of 35%, which prevented all of the ALB being taken in many years, when LPH was set at the exploitative value of 55%, the TACC could be set to take all of the ALB consistent with maintain TV at 15,000t. As a result, while the control rules prevent CLB falling below the floor TV of 15,000t, the high LPH ensures that CLB is never rises above the floor TV of 15,000t in any of the simulated time period of 46 years. Hence, average CLB = 15,000t when LPH = 55% rather than an average of 16,201t when LPH = 35%.

Figure 27 shows the impact on TACC and CLB when a TV is set at the much less conservative level of 5,000t, while LPH is set at a modest value of 35%. Potentially CLB could fall to the precarious level of 5,000t for this scenario, but it can be seen that it never falls below 9,020t, and has an average value in excess of 15,000t for these HSCR settings, because of the conservative LPH of 35%. Moreover, setting the TV at 5,000t and LPH at 35% gives an average TACC of 8,219t, which is only slightly greater than the average TACC of 7,902t when TV is set to the much more conservative level of 15,000t. However, the minimum TACC is only 4,857t, while the maximum TACC is 9,885t.

Figure 27: TACC and CLB for TV = 5,000; LPH = 35%;

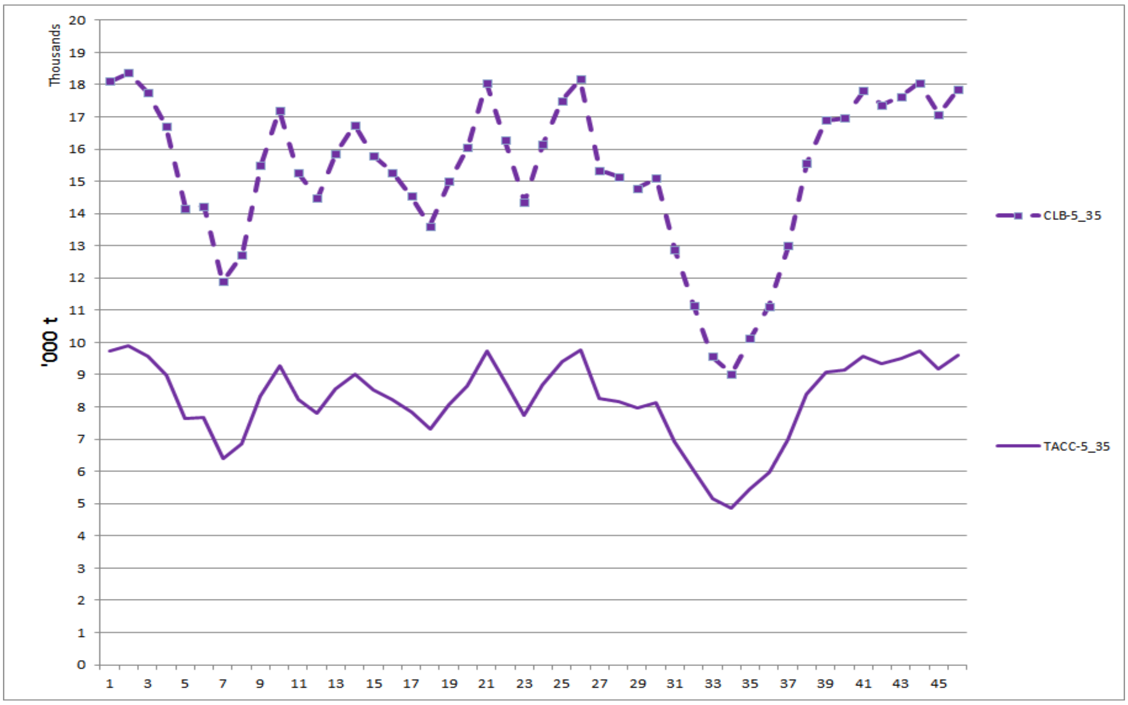
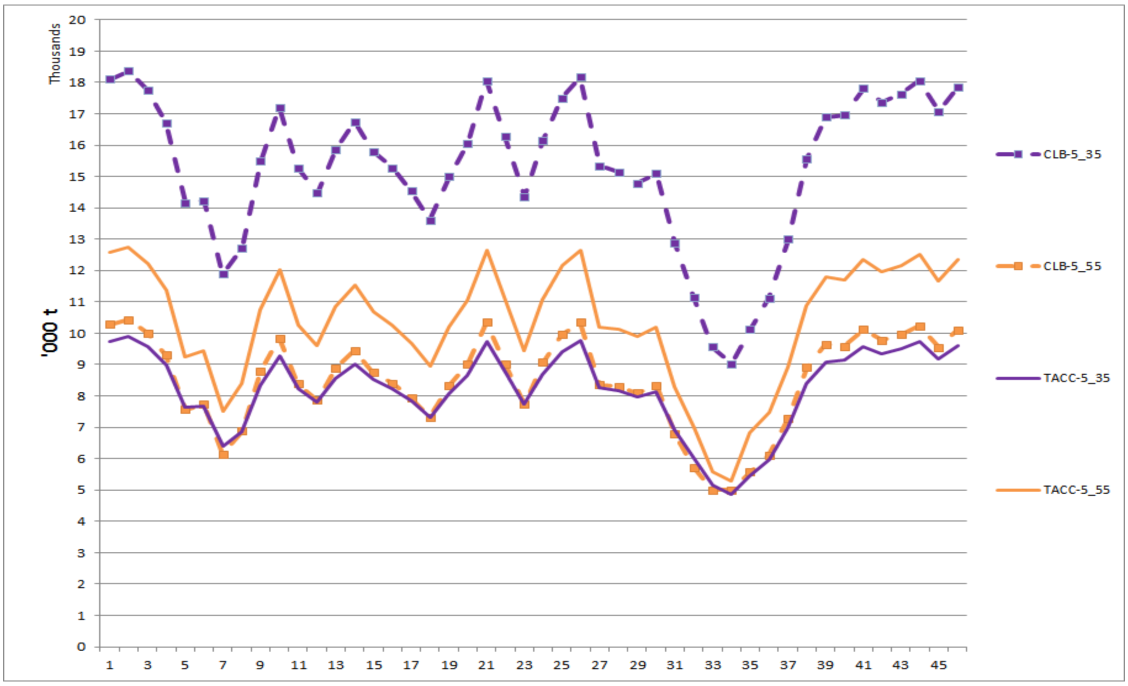


Figure 28 shows the comparison of the impact on TACC and CLB of alternative LPH settings of 35% and 55% when the floor level of CLB is set at a low TV value of 5,000t.

Figure 28: TACC and CLB for TV = 5,000; LPH = 35%; 55%



For the setting of TV = 5,000t it is apparent that the TACC is consistently greater, albeit by modest margins, when LPH = 55%, than when LPH = 35%. Thus, average TACC is 10,340t for an LPH of 55%, which is greater than the average TACC of 8,219t for LPH at 35%. Note though that at approximately 5,000t, the minimum TACC required to stop CLB falling below floor TV of 5,000t is quite similar for both LPH at 35% and LPH at 55%. On the other hand, when LPH is set at 55%, the peak annual TACC is 12,756t. This means that the P&M sector needs to invest more heavily in peak processing capacity relative to the peak production of 9,885t if LPH was set more conservatively at 35%.

The impact of alternative LPH values on CLB is far more dramatic. With an LPH of 55%, the CLB is consistently very much lower than when LPH = 35%, and in one or two years, it does fall to the low TV floor value of 5,000t. This represents a considerable risk to sustainability of the fishery. In most years though, CLB is comfortably above this floor level. On average, CLB is 8,484t even when LPH is 55%, although average CLB is much greater at 15,264t if LPH is set at 35%. Hence, when the TV is set at only 5,000t, having a lower LPH will increase catch rates considerably over what could be expected if a higher LPH was chosen.

Table 10 shows summary measures of minimum, average, and maximum values of TACC, and of CLB, for more combinations of parameter values for the harvest rule.

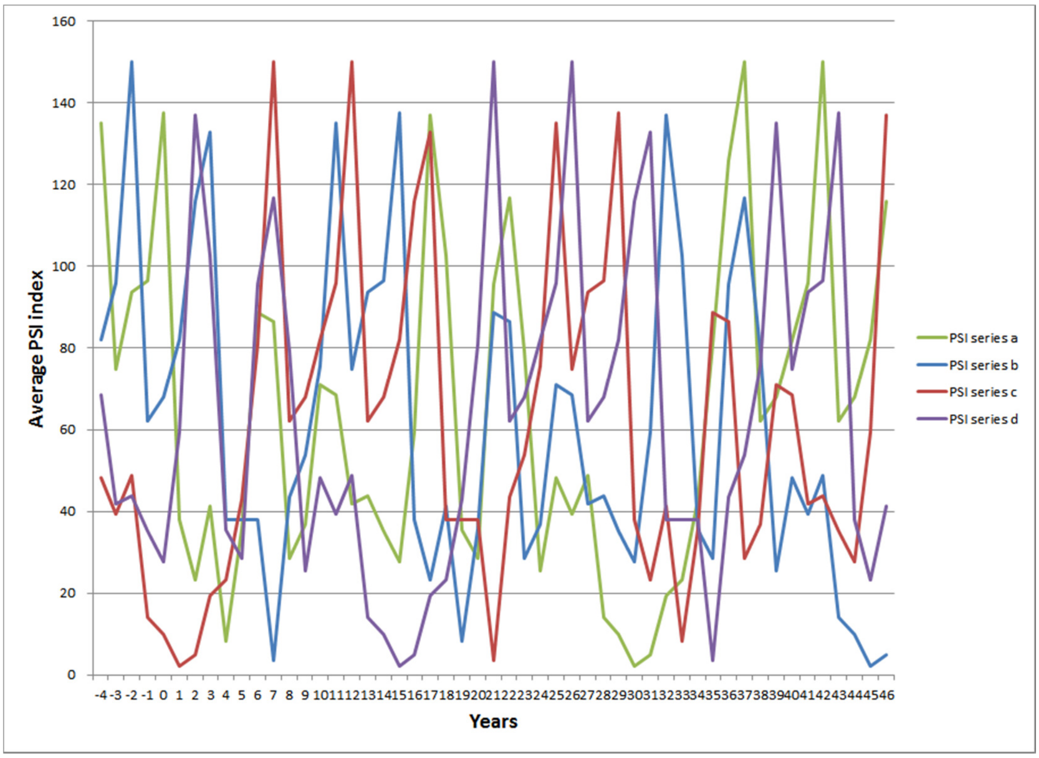
Table 10: TACC and CLB for TV = 5,000; 10,000; 15,000; LPH = 35%; 45%; 55%

		TACC			CLB		
LPH		TV=5,000	TV=10,000	TV=15,000	TV=5,000	TV=10,000	TV=15,000
	min	4,857	4,199	2,285	9,020	10,000	15,000
35	avg	8,219	8,206	7,902	15,264	15,314	16,201
	max	9,885	9,885	9,888	18,358	18,358	18,363
	min	5,318	3,885	2,285	6,500	10,000	15,000
45	avg	9,483	9,394	8,373	11,590	11,946	15,000
	max	11,566	11,566	12,125	14,136	14,136	15,000
	min	5,299	3,885	2,285	5,000	10,000	15,000
55	avg	10,340	9,957	8,373	8,484	10,070	15,000
	max	12,756	13,049	12,125	10,436	10,676	15,000

Sensitivity of the impact of HS control rules to the specific assumption about PSI

As noted above, the time series of future PSI and future annual recruitment is unknowable ex ante. The extent to which the impact of control rules on TACC is sensitive to the specific assumption about the future time sequence of PSI and recruitment, was tested using four alternative plausible year time series of PSI that mimic the past pattern of variability in PSI. These were developed to investigate how variations in this time series affected the operation of the TACC setting control rules. These four times series of PSI are illustrated in Figure 29.

Figure 29 Four Alternative Plausible Year Time Series of PSI that Mimic the Past pattern of Variability in PSI



The results in terms of impact on TACC and CLB of using each of these time series to “seed” the model are presented in Table 11. Although control rules outcomes do vary a bit depending on the particular PSI time series used to “seed” the model, these differences are comparatively insignificant relative to differences consequent on scenarios involving different control rule parameter values. For this reason, many of the results reported in the rest of this report are for PSI series a only.

Table 11 Impact on TACC and CLB of Using Alternate PSI Time Series

		Average TACC			Average CLB		
LPH	PSI	TV=5,000	TV=10,000	TV=15,000	TV=5,000	TV=10,000	TV=15,000
35	a	8,219	8,206	7,902	15,264	15,314	16,201
	b	8,495	8,495	8,288	15,777	15,777	16,274
	c	8,206	8,192	7,860	15,239	15,289	16,255
	d	8,321	8,308	8,023	15,454	15,503	16,344
45	a	9,483	9,394	8,373	11,590	11,946	15,000
	b	9,815	9,778	8,750	11,997	12,110	15,000
	c	9,467	9,363	8,354	11,571	11,984	15,000
	d	9,611	9,519	8,578	11,747	12,114	15,000
55	a	10,340	9,957	8,373	8,484	10,070	15,000
	b	10,712	10,334	8,750	8,765	10,076	15,000
	c	10,323	9,938	8,354	8,470	10,058	15,000
	d	10,491	10,156	8,578	8,608	10,083	15,000

Impact of Harvest Rules on Catching Sector Operations

Estimates for the catching sector component are based on required effort. The specification used is as follows;

- Required pot lifts: $PL_t = 13{,}000{,}000*(TACC_t/ALB_t)$

  where ALB_t = available legal biomass in yr t

To ensure that the catching sector has the capacity to catch all of the TACC even in those years when TACC is large and/or abundance is relatively low, it was assumed that competition would ensure that pot lift capacity would equal maximum PL_t required over the 46 year simulation period. Furthermore, it was assumed that it would be uneconomic to attempt to catch WRL on about 115 days per year, due to considerations such as bad weather, poor catchability, etc. Hence, maximum fishing days (FD)/year was specified to equal 250 days. Furthermore, it was assumed that on average, each boat would fish with 180 pots. If fleet size is constant from year to year, and just sufficient to ensure that the catching sector has the capacity to catch all of the TACC in all years, then the number of boats equals $\max(PL_t)/45{,}000$.

Since the number of fishing days required to catch the TACC in any given year will be less than or equal to 250 days, fishing days in year t (FD_t) will equal $PL_t/(\#\ boats*180)$, and catching capacity utilisation will equal $FD_t/250$.

Figure 30: Fishing Days: TV = 5,000, 15,000; LPH = 35%, 55%

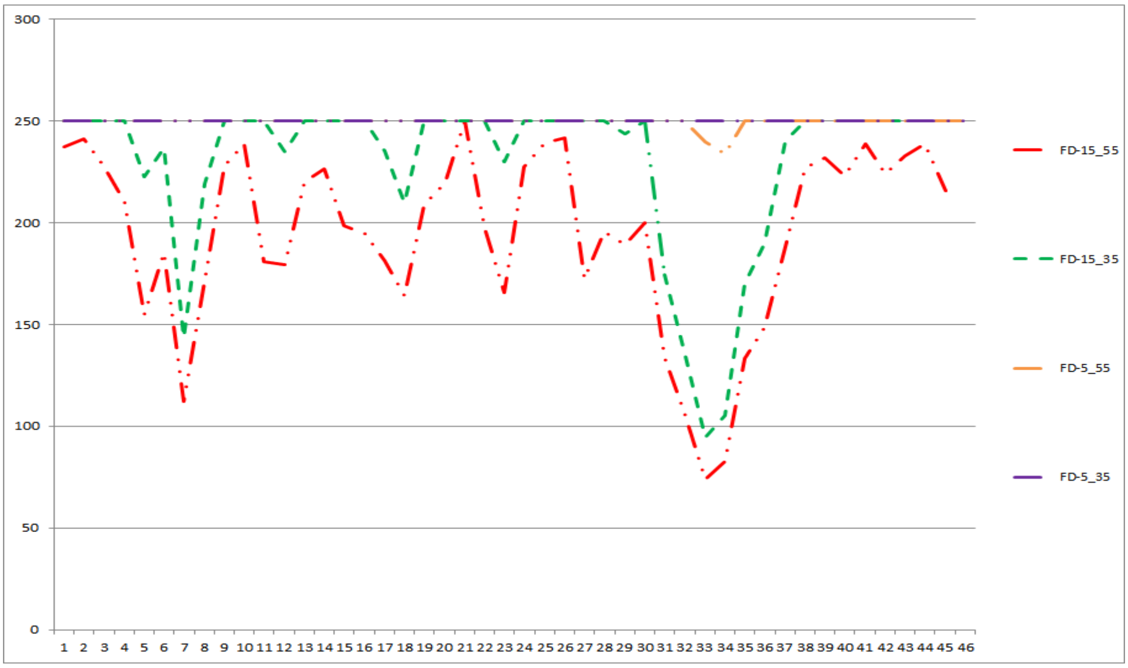


Figure 30 shows annual fishing days required for PSI series a when TV equals either 5,000 or 15,000, and when LPH equals either 35% or 55%. If TV is 15,000, it can be seen that in almost all years, the fleet will take less than 250 days to catch all available quota, and in all years, the number of fishing days for LPH = 35% is greater than for LPH = 55%.

Conversely, if TV is only 5,000t, the fleet will need ALL of the specified 250 days in ALMOST ALL years to catch all available quota if LPH = 55%. However, if LPH = 35%, ALL 250 days will be needed in EVERY year. In fact, it can be seen from Table 12 that ALL 250 days will be needed in EVERY year if LPH = 35% or 45% as long as TV = 5,000t, and that on average, 249 days will be needed if LPH = 55%. On the other hand, if TV = 15,000t, as few as 74 days will be needed if LPH = 45% or 55%, and on average only 196 days will be needed in both these cases, so the fleet will remain tied up in port for many weeks in most years because all available quota has been caught.

Table 12: Pot Lifts, # boats, FD for PSI series a when TV= 5,000; 10,000; 15,000; LPH= 35%, 45%, 55%,

		# boats					
LPH		TV=5,000	TV=10,000	TV=15,000			
35		101	101	101			
45		130	130	129			
55		159	159	129			
		PL			FD		
LPH		TV=5,000	TV=10,000	TV=15,000	TV=5,000	TV=10,000	TV=15,000
35	min	4,550,000	3,844,292	1,718,607	250	211	94
	avg	4,550,000	4,526,245	4,188,363	250	249	230
	max	4,550,000	4,550,000	4,550,000	250	250	250
45	min	5,850,000	3,637,446	1,718,607	250	155	74
	avg	5,850,000	5,668,556	4,547,676	250	242	196
	max	5,850,000	5,850,000	5,811,137	250	250	250
55	min	6,688,580	3,637,446	1,718,607	234	127	74
	avg	7,133,495	6,347,795	4,547,676	249	222	196
	max	7,150,000	7,150,000	5,811,137	250	250	250

Required fleet size also differs significantly between the HSCR scenarios, although for all TV levels, only 101 boats will be needed if LPH = 35%. Furthermore, irrespective of the TV level chosen, a larger fleet will be needed, the greater the value of LPH.

Moreover, although not shown in **Table 12, t**he required fleet size for most HSCR scenarios is exactly the same for all PSI series. The only exceptions are for TV = 15,000, when for PSI series c and LPH = 45% or 55%, the required number of boats is 126 rather than 129. The average number of fishing days required for any given HSCR scenario also is quite insensitive to the PSI series, but does vary by about 2% between the PSI series for some HSCR scenarios.

Impact of Harvest Rules for Catching Sector Economics

Catching sector economics is based on the following specification. Each year, catching costs include both a variable component that is directly proportional to the required number of fishing days (FD_t) for that year, and a fixed component that is independent of either the $TACC_t$ or FD_t. Both per unit variable costs and fixed costs are assumed to be constant over time, and across all HSCR scenarios. Variable costs (VCC), include per trip costs of $1,560 for fuel, bait, repairs and maintenance, including replacing lost pots, etc., but excludes the 45% wage share for crew, which is deducted from catch revenue. In any given year,

- $VCC_t = FD_t$* costs/trip * # boats = FD_t* $1,560 * # boats

For each boat, fixed catching costs of $159,000 per boat per year includes boat depreciation, annual boat and engine overhaul costs, cost of licences, other fixed costs including land based costs, the opportunity cost of investment in boats and other capital items, etc., but excludes acquisition or finance costs for catch quota.

- (FCC_t) = $159,000* # boats

Based on the available evidence outlined above, demand is assumed to be perfectly elastic in the main model, so all product prices, including beach, wholesale and retail, are independent of fluctuations in the $TACC_t$. [38]

The following specification of catching sector economic returns in year t (CER_t) reflects this approach:

– $CER_t = TACC_t$*beach price(P)*(1- 45% wage share)–VCC_t – FCC_t
  = $TACC_t$ * \$33 * 55% - PL_t*\$8.67 - \$159,000* # boats
  = $TACC_t$*(\$18.15 – \$112,666,667/ALB_t) - \$159,000*# boats

As not all sections of industry accept that demand is highly elastic, a variation on the above that assumes a somewhat inelastic demand curve for beach prices also was run. The results of these runs will be discussed later in this report.

Table 13: Net Economic Returns for Catching Sector (CER) for PSI series a when LPH = 35%, 45%, 55%, TV = 5,000 10,000 15,000

	CER - 46 year period NPV (\$m)		
LPH	TV(CLB)=5,000	TV(CLB)=10,000	TV(CLB)=15,000
35%	\$1,681.587	\$1,681.039	\$1,635.298
45%	\$1,806.305	\$1,803.228	\$1,633.620
55%	\$1,797.416	\$1,778.294	\$1,633.620
	minimum annual CER (\$m)		
LPH	TV(CLB)=5,000	TV(CLB)=10,000	TV(CLB)=15,000
35%	\$31.027	\$25.196	\$8.886
45%	\$23.080	\$16.240	\$3.981
55%	\$10.400	\$11.184	\$3.981

For PSI series a, summary measures of net economic returns to the catching sector, measured as the net present value of the surplus stream over 46 years, are shown in the top half of Table 13 for various combinations of TV and LPH settings. It can be seen that setting TV = 5,000t and LPH = 45% generates the greatest NPV of \$1,806m, but that a much lower risk strategy involving setting TV = 10,000t and LPH = 45% generates an NPV of \$1,803m which is only marginally smaller. However, for the most conservative strategy of setting TV = 15,000t and LPH = 35%, NPV is only \$1,635m, which is a non-trivial reduction in net economic returns to the catching sector.

While not shown, for any given combination of TV and LPH settings, the magnitude of the CER NPV does vary by up to 17% between the four PSI series evaluated. Nevertheless, such variation from one PSI series to another is consistent across all HSCR scenarios, so the above qualitative results, such as that TV = 5,000t and LPH = 45% generates the greatest NPV, are true irrespective of the PSI series evaluated. This finding gives some confidence that the relative rankings of the

[38] The model is developed in real terms, which means that the assumption of perfect price elasticity leaves the real price unchanged. Nominal price can increase at the rate of inflation. This is consistent with the analysis of beach prices reflected in Figure 22.

HSCR scenarios are robust, at least in the sense of not being sensitive to intrinsic uncertainty about the specific form of the PSI series.

Because average returns as captured by NPV hide the risk of significant downturns in annual returns that might bankrupt at least some firms, the bottom half of Table 13 shows estimated minimum net economic returns for the worst financial year in the simulated time sequence of 46 years. Plainly, more conservative strategies involving TV = 15,000t, or more exploitative strategies involving LPH = 55%, run the greatest risk of a disastrous downturn in catching sector annual financial returns.

Impact of Harvest Rules for P & M Economics

The processing and marketing (P&M) sector consists of a handful of small to medium size commercial entities that regard comprehensive information on the economics of their operations as commercially sensitive. Hence, many details of the economics for this sector are not publicly available, and the following specification in the model had to be based on such limited sources of information as were publicly available, plus insights gained from interviewing industry participants.

Variation in inter-year throughput that the sector faces is determined almost entirely by the size of the annual TACC. Nonetheless, the sector must maintain sufficient capacity to process and market the largest likely TACC for the foreseeable future. In addition to the cost of acquiring WRL to process and sell to markets, variable costs also will include those costs, such as power and non-core labour, that can be varied from year to year depending on the size of the TACC. Fixed costs will be those costs, such as capital costs, that cannot be varied from year to year, and whose magnitude is determined by the required capacity to handle the largest expected catch in the long run.

Based on available evidence, the supply of inputs to the P&M sector is assumed to be perfectly elastic, so per unit cost parameters are assumed to be independent of fluctuations in the $TACC_t$. Furthermore, as discussed above, in the long rum wholesale demand is assumed to be highly elastic, so both per unit variable cost and fixed cost parameters are assumed to be constant over time and across all HSCR scenarios.

Annual P&M operating surplus is defined as ($TACC_t$ * P&M gross operating margin); where:

- P&M gross operating margin= wholesale price – beach price – variable P&M costs/kg
= $5.00/kg

Annual P&M fixed costs are defined as

- P&M = P&M capacity*$2. 00/kg = max ($TACC_t$) *$2.00/kg

So P&M sector economic returns in year t (PER_t) = $TACC_t$* $5.00/kg - max ($TACC_t$)* $2.00/kg

Summary measures for PSI series a of net economic returns to processing, as measured by net present value of annual P&M sector economic returns over 46 years, are shown in the top half of Table 14 for various TV and LPH settings. It can be seen that setting TV = 5,000t and LPH = 55% clearly generates the greatest NPV of $481m. The NPV of $440m for the lower risk strategy of TV = 10,000t and LPH = 45% is markedly lower, but considerably greater than the NPV of $366m for the most conservative strategy of setting TV = 15,000t and LPH = 35%. Again, the relative rankings of the HSCR scenarios are not sensitive to the specific form of the PSI series.

The bottom half of Table 14 shows estimated minimum net economic returns for the worst financial year in the simulated time sequence of 46 years. These estimated simulation results show that the P&M sector will incur losses for almost all of the strategies apart from the more biologically risky strategies involving TV = 5,000t and LPH = 35% or 45%. Notably, this sector is projected to sustain significant losses that could prove financially fatal if the most conservative strategies, involving TV = 15,000t, were adopted.

Table 14: Net Economic Returns for P&M Sector (PER) for PSI series a when LPH = 35%, 45%, 55%, and TV = 5,000 10,000 15,000

	PER - 46 year period NPV ($m)		
LPH	TV(CLB)=5,000	TV(CLB)=10,000	TV(CLB)=15,000
35%	$391.143	$390.486	$365.560
45%	$445.793	$439.763	$324.132
55%	$480.846	$433.357	$324.132
	minimum annual PER ($m)		
LPH	TV(CLB)=5,000	TV(CLB)=10,000	TV(CLB)=15,000
35%	$4.515	$1.224	-$8.350
45%	$3.460	-$3.706	-$12.825
55%	$0.983	-$6.672	-$12.825

Combined returns across all sectors are shown in Table 15. Because estimated net economic returns for the catching sector are much larger than for the P&M sector, the combined returns closely mirror those for the catching sector alone, except that the settings TV = 5,000t and LPH = 55% are estimated to generate the largest overall economic returns. Again though, economic returns form the somewhat more conservative settings of TV = 10,000t and LPH = 45% are nearly as large. Note also that the even more conservative settings of TV = 15,000t and LPH >= 45% are forecast to result in significant economic losses in one or more years.

Table 15: Net Economic Returns for All Sectors (AER) for PSI series a when LPH = 35%, 45%, 55%, and TV = 5,000 10,000 15,000

	AER - 46 year period NPV ($m)		
LPH	TV(CLB)=5,000	TV(CLB)=10,000	TV(CLB)=15,000
35%	$2,072.730	$2,071.525	$2,000.858
45%	$2,252.098	$2,242.991	$1,957.752
55%	$2,278.262	$2,211.651	$1,957.752
	minimum annual AER ($m)		
LPH	TV(CLB)=5,000	TV(CLB)=10,000	TV(CLB)=15,000
35%	$35.542	$26.420	$0.536
45%	$26.541	$12.534	-$8.844
55%	$11.382	$4.512	-$8.844

Summary of Key Results

Impact of Harvest Rules for WRLF Economics if demand is highly elastic

Insofar as the model simulations are concerned, the following are the major economic findings for PSI series a, and assuming perfectly elastic demand for the catch.

Catching sector economic returns are greatest when TV(CLB) = 5,000t & LPH = 45%, but NPV for the P&M sector is $445m, which is 7% less than the maximum possible. For this scenario, maximum possible catching sector NPV = $1,806m is generated by a fleet of 130 boats each fishing the maximum feasible number of 250 days per year in each and every year. Hence, average catching capacity utilization equals 100%. The annual TACC for this scenario averages 9,483t, but it fluctuates from as little as 5,318t, and up to as much as 11,566t, so average P&M capacity utilization is only 82%.

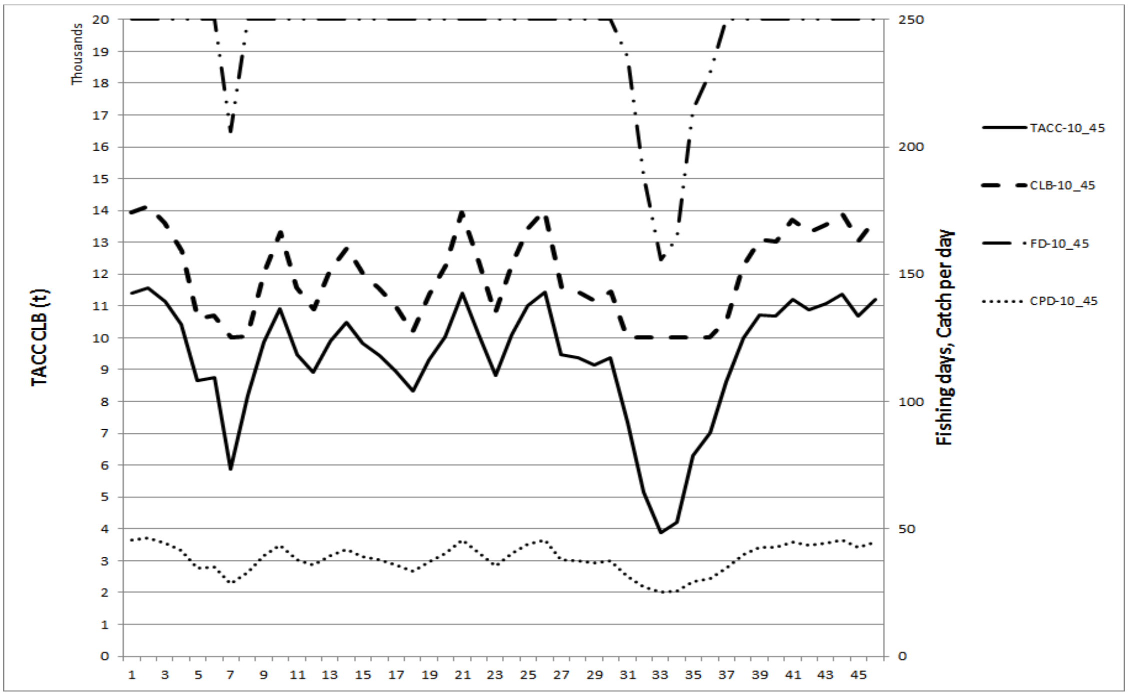
Conversely, P&M sector economic returns are greatest with an estimated NPV of $481m when TV(CLB) = 5,000t and LPH = 55%. For this scenario, catching sector NPV = $1,797m, which is fairly close to the maximum NPV of $1,806m. It is generated by a fleet of 159 boats that on average fish for 249 days per year, although for at least one year in 46, the entire TACC could be caught in just 234 days, while in other years, the maximum feasible number of 250 days is needed to catch the TACC. Consequently, average catching capacity utilization is almost 100% (i.e. 249/250). The annual TACC for this scenario averages 10,340t, but it fluctuates from as little as 5,299t, up to as much as 12,756t, so average P&M capacity utilization is only 81%.

Maximum overall economic returns for both sectors, with a combined NPV of $2,278m, is achieved when TV(CLB) equals 5,000t and LPH equals 55%. However, although these Harvest Strategy parameter values maximize combined economic returns, setting the TV(CLB) equal to 5,000t is arguably too low to satisfy the Sustainability Objective.

A somewhat more prudent policy would be to specify that TV(CLB) should be greater than or equal to 10,000t. With a floor TV value of 10,000t, the maximum combined NPV would be achieved if LPH were set at 45%. For these settings, catching sector NPV would equal $1,803m, and P&M sector NPV would equal $439m, so combined NPV would equal $2,242. A fleet of 130 boats would need all 250 days to catch the maximum TACC of 11,566t, but need only 155 days to catch the minimum TACC of 3,885t. On average, 242 days per year would be needed to catch a mean annual TACC of 9,394t, and average catching capacity utilization would be 97%, while average P&M capacity utilization would be 81%.

Note that if TV(CLB) were set at the much more conservative level of 15,000t, combined NPV would be maximized if LPH were set equal to 35%. As a result, catching sector NPV would equal $1,635m (which is 9% less than the maximum), and P&M sector NPV would equal $365m (which is 17% less than the maximum) for this sector. Combined NPV would equal $2,000m. A considerably smaller fleet of only 101 boats could still catch the maximum TACC of only 9,888t in 250 days, but would need only 94 days to catch a very small minimum TACC of only 2,285t. On average, 230 days per year would be needed to catch a mean annual TACC of 7,902t, and average catching capacity utilization would be 92%, while average P&M capacity utilization would be 80%.

Figure 31: Summary of Key Measures: TV = 10,000; LPH = 45% for PSI Series a



Arguably TV = 10,000t and LPH = 45% are the most appropriate HSCR settings. The simulated annual time series of results for this setting based on PSI series a are shown in Figure 31. The most noticeable aspects of these results relate to the two relatively short downturns in recruitment to the fishery, during which CLB fell to the floor value, and TACC had to be reduced to about 6,000t in one instance, and to about 4,000t in the other instance so as to stop CLB falling through the floor. During these periods, the season would be much shorter than the available 250 days because of low TACCs.

Impact of Harvest Rules for WRLF Economics if demand is less than highly elastic

The results presented above are for a price elasticity of infinity. In effect, this leaves real prices unchanged over the whole simulation period. As the simulation model is in real terms, this assumption effectively assumes that price to grow at the rate of inflation, and that the real price is independent of fluctuations in TACC (catch). The historical evidence as reflected in Figure 22 is consistent with this plausible assumption.

However, it is important to understand how the results may be affected if the price elasticity is less than perfectly elastic. The model has been run with two alternative price elasticity assumptions – a constant price elasticity of -2.0, and a constant price elasticity of -0.5. For the first of these variants, a 1% increase in TACC would reduce price in the market by 0.5%, all other things equal, while for the second variant, a 1% increase in TACC would reduce price in the market by 2%, all other things equal.

In developing these results, constant price elasticity demand functions were used. The two functions are;

$\log(\mathrm{v}) = 9{,}701{,}575p^{-2}$, and

$\log(v) = 35{,}644p^{-0.5}$

Where v=volume =TACC, p=price, and the constant price elasticities, η are -2.0 and -.05 respectively.

These demand curves intersect at a beach price of $42/kg, and a volume of 5,500 tonnes. In this case, the starting point is the current TACC/volume settings, and annual beach price.

As TACC increases/decreases over the harvests simulations, the beach price decreases/increases according to the relevant elasticity. Table 16 shows the beach prices that are derived from these curves for a range of TACC settings to illustrate the simulated price variation based on these two price elasticities. As TACC varies, the changes in price are greater in the second case with a price elasticity of -0.5. These price equations are included at the simulated TACCs to derive the impacts on catching sector revenues and profits across the simulations.

Table 16: Price and Volumes at Various Prices with Price Elasticity of -.5 and -2.

Reference Volume	5500t	Reference Price	$42.00
	Price elasticity=-2		Price elasticity-0.5
	Const=9,701,575		Const= 35,644
TACC	Price		Price
2,000	$69.65		$317.62
3,000	$56.87		$141.17
4,000	$49.25		$79.41
5,000	$44.05		$50.82
6,000	$40.21		$35.29
7,000	$37.23		$25.93
8,000	$34.82		$19.85
9,000	$32.83		$15.69
10,000	$31.15		$12.70
11,000	$29.70		$10.50
12,000	$28.43		$8.82
13,000	$27.32		$7.52
14,000	$26.32		$6.48
15,000	$25.43		$5.65
16,000	$24.62		$4.96

The simulation model sets TACC according to harvest rules that are designed to satisfy threshold biomass outcomes. As such, the setting of the TACC in the model is not conditional on the price at which the catch will be sold. The revenue implications considered below therefore reflect the impact of price variations associated with TACC variations on the assumption that the TACC set according to HSCR is in fact caught and delivered to market within the year.[39]

[39] Of course, within any one year, the marketing of the TACC has to be done so as to get the best return for the industry. Two years with the same TACC may not have the same intra year catch pattern. The intra year catch pattern will be influenced by the marketing objectives. Clearly, processors will adapt daily, weekly and monthly beach prices to get the pattern of catch that best suits the market into which they are selling, thereby maximising revenue for the given annual TACC.

Figure 32 Beach Prices when Price Elasticity = -.5 and -2: TV = 10,000 & LPH = 45% for PSI Series a

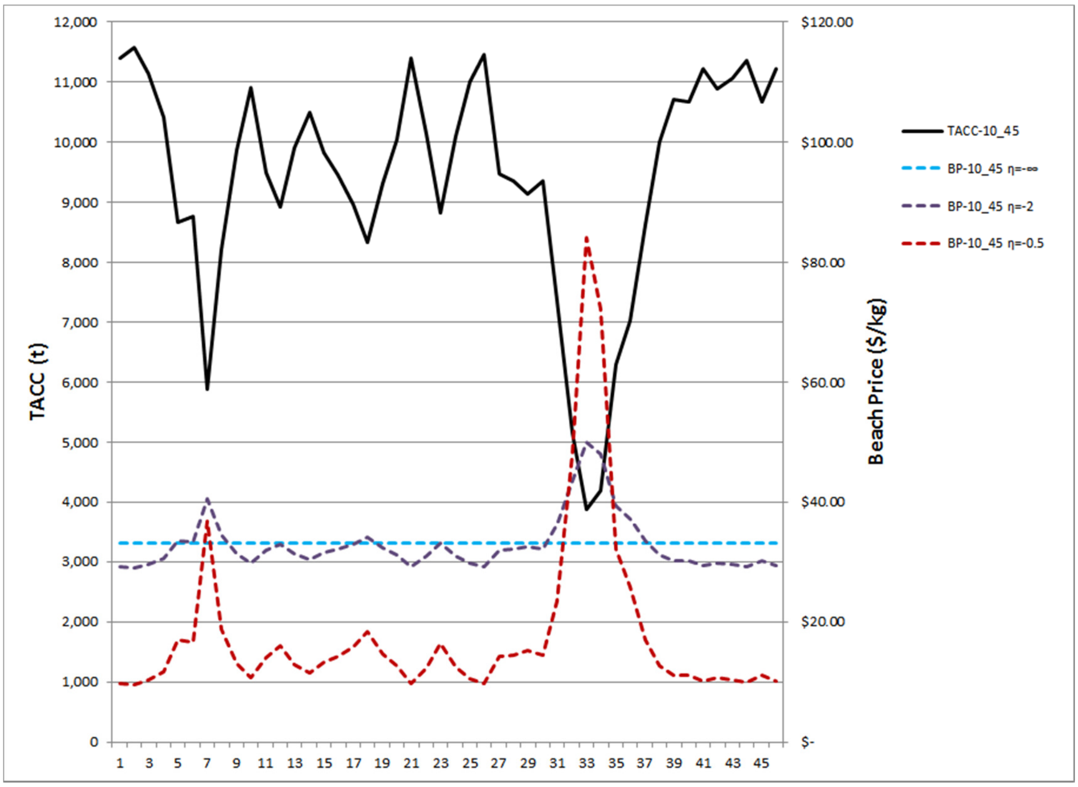


Figure 32 illustrates the effect of the three different assumptions about demand elasticity on the calculated time series of beach prices for PSI series a when the preferred harvest rules settings TV = 10,000t and LPH = 45% are selected. As already noted, the beach price does not vary as TACC varies if demand is infinitely elastic. When demand is less than perfectly elastic (η = -2.0 and η = -.05), beach price will be higher when TACC is lower, and vice versa, and the variations in beach prices will be greater, the more inelastic the demand curve.

The corresponding time series of revenue and net economic returns for the harvest sector are illustrated in Figure 33 and Figure 34 respectively. When demand is completely elastic (i.e. η = -∞), variability of catching sector revenue mimics variations in the TACC, but fluctuations in catching sector revenue diminish as demand becomes less elastic. Not shown is the case when η = -1.0, when fluctuations in beach price just offset changes in TACC, so catching sector revenue is constant from year to year even though the TACC changes. Moreover, although regarded as highly unlikely, if demand was inelastic (e.g. η = -0.5), then as can be seen from Figure 33, movements in catching sector revenue would be countercyclical relative to changes in the TACC.

Figure 33 Catching Sector Revenue when Price Elasticity = -.5 and -2: TV = 10,000 & LPH = 45% for PSI series a

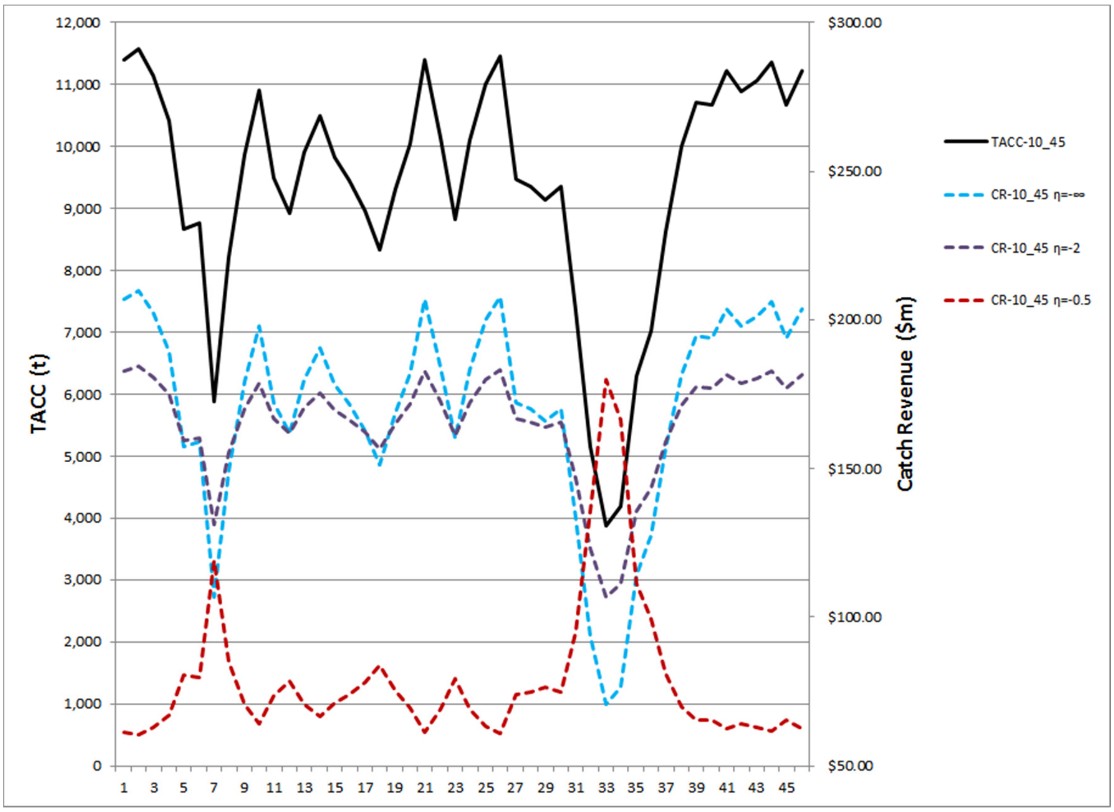


Figure 34 Catching Sector Profits when Price Elasticity = -.5 and -2: TV = 10,000 & LPH = 45% for PSI Series a

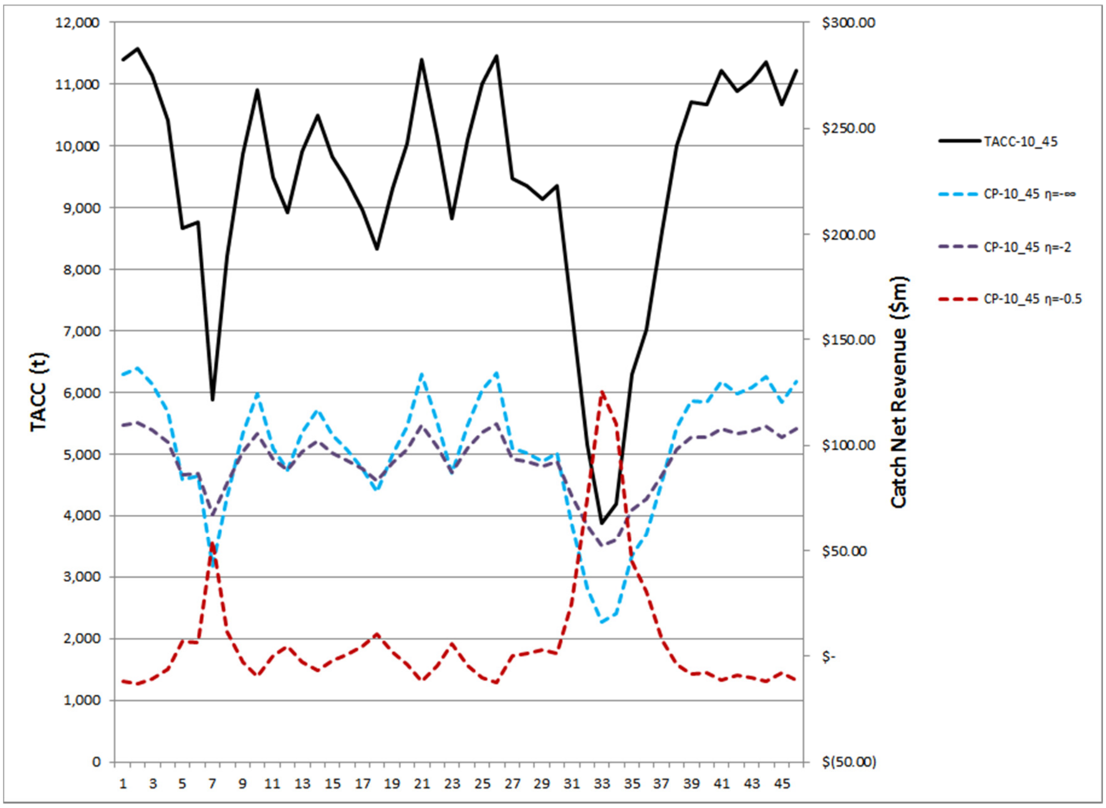
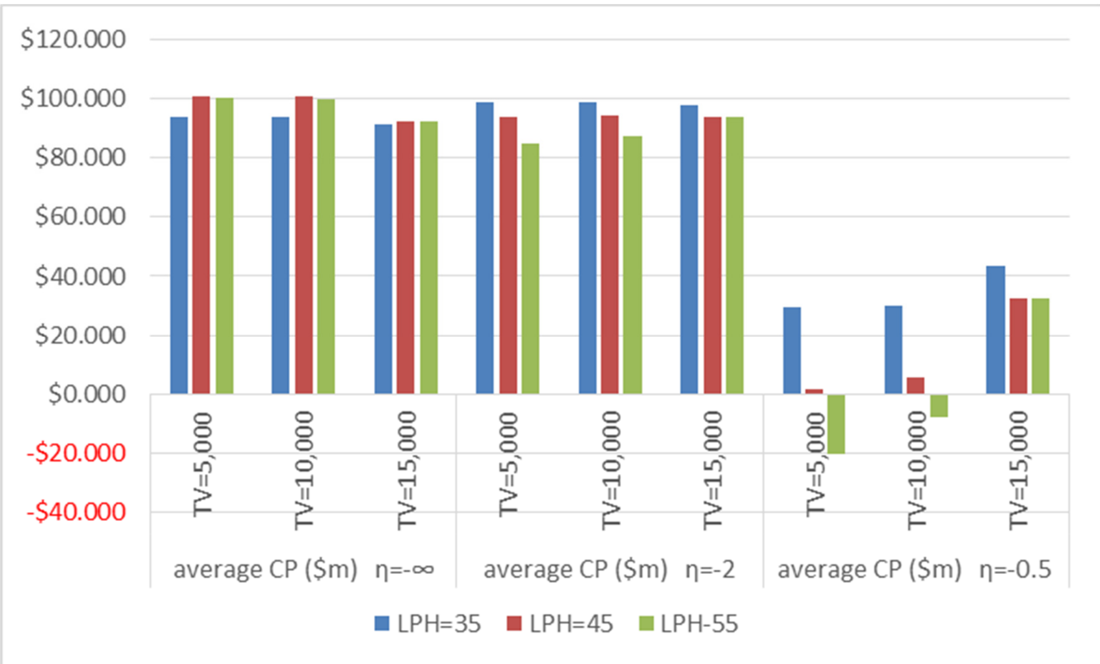


Figure 35: Impact of Price Elasticity on Catching Sector Profit



Catching sector profit for combinations of price elasticity (-∞, -2, -0.5) for all HSCR settings (TV = 5,000t, 10,000t, 15,000t; LPH = 35%, 45%, 55%), and with PSI series a, are summarized in Figure 35 and Table 17. With a less elastic demand value of -2 compared to -∞, catching sector profits are slightly higher if LPH=35% rather than 45%; and if TV=10,000 rather than 5,000, although the differences between TV=5,000 and TV=10,000 are marginal. However, with an inelastic demand of -0.5, the most conservative TACC setting control rules (TV = 15,000t; LPH = 35%), generate by far the largest catching sector profits, and are the only options for ensuring profitability. This is because increases in TACC and catch have a disproportionate effect on reducing price. However, as previous analysis has showed, Western Rocklobster has substitutes and there is evidence of market integration. Under these scenarios, a price elastic demand estimate is favoured.

Table 17: Catching Sector Profit under Different Price Elasticity Assumptions

	CER ($m) η=-∞		
LPH	TV(CLB)=5,000	TV(CLB)=10,000	TV(CLB)=15,000
35%	$92.052	$92.010	$89.435
45%	$98.659	$98.616	$89.959
55%	$98.047	$97.892	$89.959
	CER ($m) η=-2		
LPH	TV(CLB)=5,000	TV(CLB)=10,000	TV(CLB)=15,000
35%	$97.656	$97.675	$96.733
45%	$92.702	$93.150	$92.530
55%	$83.752	$86.556	$92.530
	CER ($m) η=-0.5		
LPH	TV(CLB)=5,000	TV(CLB)=10,000	TV(CLB)=15,000
35%	$30.512	$31.285	$45.652
45%	$2.962	$7.304	$35.262
55%	-$19.035	-$6.002	$35.262

Governance and Supply chain in the Western Australian West Coast Scalefish Fishery

Finfish are caught in a number of multispecies fisheries in Western Australia.

Three species are defined as the iconic species caught in the West Coast Demersal Fishery– West Australian Dhufish, Snapper and Baldchin Groper. These are major targeted species for recreational fishers. Snapper and West Australian Dhufish are major species for commercial fishers. These three species are also the major indicator species used to judge the state of stocks across the multi species fishery pursuant to making management decisions regarding harvest strategies and regarding catch allocation between recreational and commercial fishers.

Apart from the designated Shark Bay recreational Snapper catch, these fisheries do not use direct output controls. Both the commercial and recreational sectors have a mix of controls. Recreational fishers require a recreational license and boat license to fish for these species. They have fixed bag and possession limits, or, as in part of one fishery, a limited number fish tags. Commercial fishers are managed through a mix of time and gear constraints.

The bulk of the Snapper catch is delivered to the metropolitan region for sale through processors/wholesalers with primary outlets being seafood shops and restaurants. The major supermarket chains are not large buyers/sellers of the premium priced species including Snapper, West Australian Dhufish and Baldchin Groper.

Overview of the Fishery

There is an extensive spread of ocean and many demersal species caught (more than 200 species) along the Western Australian coastline. At the time this research project was initiated, there was particular interest in the demersal scalefish catch from temperate waters of the lower South West coast into the warmer waters of the Gascoyne. This was because the available data, at that time, from catch and effort monitoring and mortality assessments of key ‘indicator’ species[40] (Snapper, West Australian Dhufish and Baldchin Groper) pointed to overfishing of the demersal scalefish, or, as it was commonly known the ‘wetline’ fishery.

Fisheries managers assessed that substantial reductions in catch would be required to restore resource sustainability in the fishery. This posed interesting fisheries management challenges in addressing and managing the required catch reductions by the various resource users, in particular commercial and recreational, but also including charter fishing operators[41].

Once the extent of the required catch reduction to restore stock sustainability was established from stock assessment, the key management decisions that followed related to:

- determining how this reduced catch level would be shared (administratively or market based allocation methods) among the competing resource users and, if the former, both initially (i.e. which users should wear proportionally more or less of the required catch reduction) and over time; and then, when

[40] These species were reportedly chosen because they are caught insubstantial numbers and because of their biological characteristics (longevity and slow growing and reaching sexual maturity) which apparently together they are likely to show signs of too much fishing before other species.

[41] Customary or indigenous use was regarded as not significant and discounted in addressing and implementing the required harvest strategy to restore resource sustainability in the fishery.

- determining how the reduced ‘allowable’ catch levels for each of the user groups is to be achieved (i.e. the design of the fisheries management rules to keep catch levels for each user groups within their respective reduced allowable levels).

For both these management issues, a significant challenge for the fisheries managers is how to incorporate economic considerations into the governance structure particularly where it is mandated that sustainable use of the resource is to be is based on optimizing economic benefits to the community as it is in jurisdiction of this case study.

The substantially reduced ‘allowable’ commercial catch brought with it consideration of the likely impact on prices and incomes from commercial fishing, at least for a foreseeable period pending the return to sustainability of the resource stocks. The design of the management rules to achieve the reduced catch levels, and the scope to achieve increased prices for the reduced commercial catch, became important determinants of opportunities for economic viability within the harvest sector. These governance issues within the demersal scalefish fishery, where West Australian Dhufish and Snapper catches are particularly important as key indicators species for monitoring stock status within the fishery, became a primary focus of this case study.

Main Fisheries

Whilst many demersal scalefish species (over 200) are caught in the West coast fishery, the typical species caught in waters of each of the respective inshore (out to the 250m isobath) and offshore (over 250m isobath to the 200 nm AFZ boundary) management areas of the fishery are shown in Table 18 below.

Table 18: Typical Demersal Scalefish Species Caught in the West Coast Fishery

Area	Typical Catch
Kalbarri Inshore Area	Dhufish, Snapper, sweetlip emperor
Mid-West Area	Dhufish, Snapper, sweetlip emperor
Abrolhos (Sub-Area)	Baldchin Groper, Snapper
Metropolitan Area	Dhufish, Snapper
South West Inshore Area	Dhufish, Snapper, Bight redfish
Offshore Area	Hapuku, ruby snapper, blue eye trevalla, Bass Groper, and grey banded cod

Sources: Fisheries Management Paper No. 249, July 2013 Status Reports of the Fisheries and Aquatic Resources of Western Australia 2012/13

By far the largest catch volumes of West Australian Dhufish occur in the West Coast Demersal Scalefish (Interim) Managed Fishery, whilst this Fishery and the adjoining Gascoyne Demersal Scalefish Managed Fishery account for the largest catches of Snapper.

Three other commercial fisheries also catch these species, collectively representing around 10% of the commercial catch[42]. A further eight other method-based commercial fisheries[43] can take demersal scalefish but reportedly take negligible amounts.

A map showing the location of the Managed Fisheries, which account for significant catches of these species, is presented in Figure 36.

The Western Australian commercial harvest by volume and value is shown in Table 19 and Table 20.

The major species caught by volume are Snapper (479t), emperors (498t) and tropical snappers (1680t).

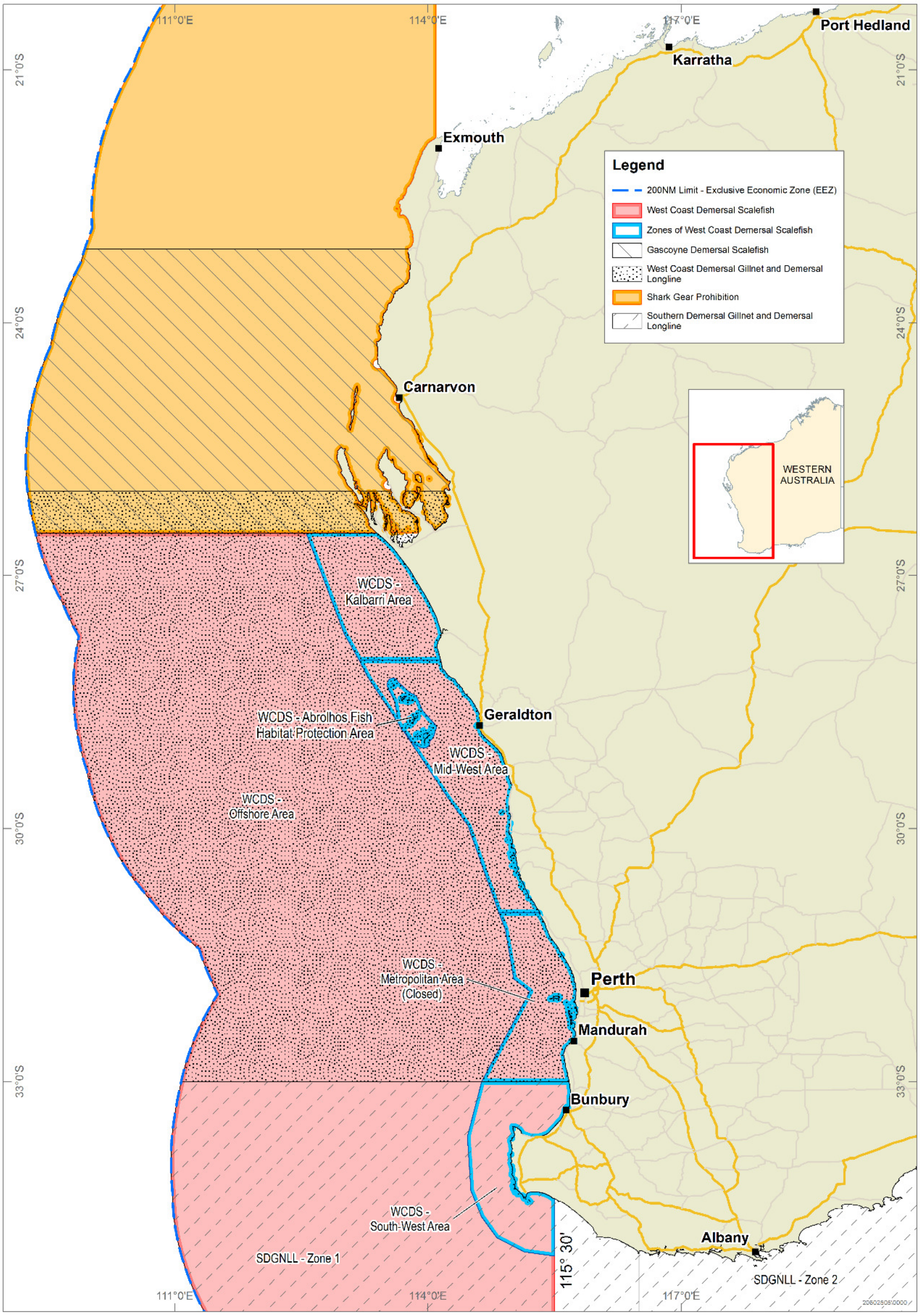
Snapper (*Pagrus auratus*) is arguably the premier fish species for consumers seeking high quality local fillets and whole fish. The catch is sold entirely locally. Snapper currently commands a premium price. There is competition for Snapper from other locally caught finfish and from imported finfish, including imported Snapper.

Locally, the major competition for Snapper is from emperors, especially red emperor (*Lutjanus sebae)* and from tropical snapper, especially Goldband Snapper (*Pristipomoides multidens*). A major potential source of import competition is NZ Snapper (*Pagrus auratus*). Major supermarkets offer Saddletail Snapper *(Lutjanus malabaricus*) imported from the Northern territory

[42] These fisheries include the West Coast Demersal Gillnet and Demersal Longline (Interim) Managed Fishery, the Joint Authority Southern Demersal Gillnet and Demersal Longline Managed Fishery and the Commonwealth managed Western Deepwater Trawl Fishery. The latter two reportedly take minimal demersal scalefish on the west coast.

[43] These fisheries include; the South West Trawl Managed Fishery, the Cockburn Sound Line and Pot Managed Fishery, the Cockburn Sound Fish Net Fishery, the Marine Aquarium Fish Managed Fishery, the South West Salmon Fishery, the West Coast Beach Bait Fish Net Managed Fishery, the West Coast Purse Seine Fishery, and the Western Rocklobster Fishery (which has an exemption to retain demersal scalefish caught in rock lobster pots).

Figure 36: West Coast Demersal Fishery



Source: Department of Fisheries, Western Australia.

Table 19: Western Australian Commercial Fish harvest Volumes

	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
Fish	**t**	t	t	t	t	t	t	t	t	t	t	t	t	t	t
Tuna	23	21	34	17	27	38	15	12	18	39	31	2	2	3	1
Shark	1760	1708	1456	1618	1898	2039	2228	2717	1853	1466	1725	1572	1194	980	887
Sharkfin			na	na	na	0	0	na	na	na	na	na	na	na	na
Western Australian salmon	2608	1752	2598	2414	2622	1858	2483	255	2043	1047	685	986	342	101	201
Cobbler	222	270	306	227	220	278	210	193	143	148	209	169	151	68	64
West Australian Dhufish	232	210	213	224	257	258	239	227	212	167	117	86	81	74	86
Spanish mackerel	560	368	338	350	436	478	488	347	281	296	321	312	295	286	276
Sea mullet	393	372	387	265	333	326	305	250	202	224	259	245	274	234	191
Yelloweye mullet	178	138	82	66	50	54	52	47	39	39	34	25	30	24	22
Australian sardine	7037	3633	1463	870	1610	2064	1813	828	2038	1873	1835	2108	2651	2 371	2 410
Australian herring	764	744	841	761	598	530	438	278	353	230	285	182	214	147	119
Whiting	281	240	260	228	175	171	163	188	185	144	145	179	152	169	165
Bream		116	109	103	108	121	128	159	123	134	123	103	112	109	95
Emperor		968	925	879	861	986	1325	1536	1024	802	579	418	429	535	498

Snapper	2425	788	740	835	855	843	817	680	693	588	470	425	444	456	479
Rockcod		294	331	287	279	294	414	450	459	426	351	326	314	345	393
Tropical snapper		1512	1273	1384	1591	1700	1954	2239	2066	1739	1703	1714	1586	1 673	1 680
Other	3926	3580	4951	4157	4602	4340	4402	3858	3642	2236	1597	1381	1720	1 600	1 546
Total	20409	16714	16307	14685	16522	16378	17474	15882	15374	11598	10469	10233	9991	9 175	9 113
Other NEI b			63	92	72	124	87	91	66	81	314	195	171	107	43
Total wild caught	38478	38452	40611	34473	32948	40969	40413	40777	33887	27051	29105	25965	23217	22 769	18 285

Table 20: Western Australian Commercial Fish Harvest Values

	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
Fish		$'000	$'000	$'000	$'000	$'000	$'000	$'000	$'000	$'000	$'000	$'000	$'000	$'000	$'000
Tuna	95	103	203	109	203	249	94	82	101	276	218	12	19	18	9
Shark	4229	4575	3609	4122	4479	4803	5631	6585	5092	4091	4983	4301	3705	3 024	3 725
Sharkfin			na	1133	1292	1367	1521	2040	1199	895	1091	1002	721	613	407
Western Australian salmon	1252	841	1299	870	1127	798	1068	540	879	451	294	424	147	44	121
Cobbler	626	960	1126	700	759	915	676	644	538	583	776	752	700	404	356
West Australian Dhufish	2066	1987	1900	1986	2277	2301	2133	3070	2878	2257	1599	1177	1084	1 009	1 479

Spanish mackerel	2883	2182	2115	2221	2762	2560	3174	2250	1704	1792	1937	1886	1783	1 732	2 517
Sea mullet	1080	779	744	555	696	519	671	548	444	493	572	538	604	519	581
Yelloweye mullet	178	208	82	59	44	47	46	69	58	58	50	36	45	36	31
Australian sardine	4823	2470	1244	783	1449	1858	1632	1645	1833	1686	1651	1898	2386	2 134	2 676
Australian herring	337	306	336	304	239	212	174	111	141	92	113	72	85	59	127
Whiting	1100	1018	1017	955	701	824	744	945	881	713	734	908	729	806	1 071
Bream		449	429	392	434	467	504	737	538	568	534	461	538	510	637
Emperor		2765	2754	2801	2743	3337	4053	4025	3670	2839	2121	1477	1543	1 837	2 814
Snapper	8084	3611	2364	3941	4036	4169	4044	3367	3428	2912	2330	2109	2203	2 265	4 017
Rockcod		1282	1546	1370	1316	1370	1847	2301	2265	2019	1618	1447	1414	1 618	3 224
Tropical snapper		7098	6631	6547	7618	8490	10018	11829	10932	9400	9512	9806	8927	9 143	13 984
Other	12346	7422	7914	7415	7732	8241	7925	7509	7142	5358	4773	4325	4682	4 139	6 185
Total	39099	38056	35313	36263	39907	42527	45955	48297	43723	36483	34906	32631	31315	29 910	43 961
Other NEI b			188	275	214	371	259	272	199	241	943	586	512	321	129
Total wild caught	348404	403576	547707	435926	434372	431501	400742	414834	417653	352382	330383	291473	272148	284 800	275 520

Source: Australian Fisheries Statistics

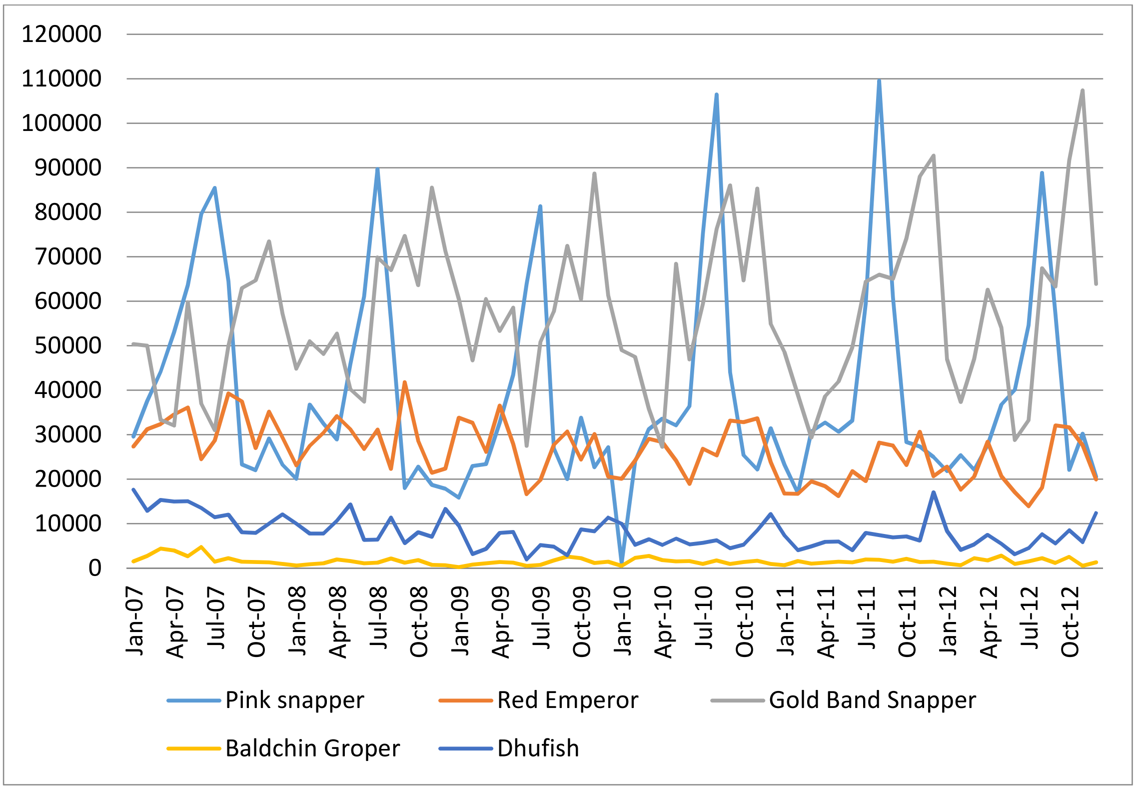
Markets and Prices

Catch History

The catch data for the main commercial finfish species in WA is shown in Figure 32. This is the finfish harvest across all fisheries. The relatively small catch of West Australian Dhufish is evident, as is the commercially insignificant catch of Baldchin Groper. The average annual catch for Snapper is 467,000 kg, for Goldband Snapper 685,000 kg, for red emperor 316,000 kg for West Australian Dhufish 97,000 kg and for Baldchin Groper 19,000 kg. Annual catch is shown in Table 15.

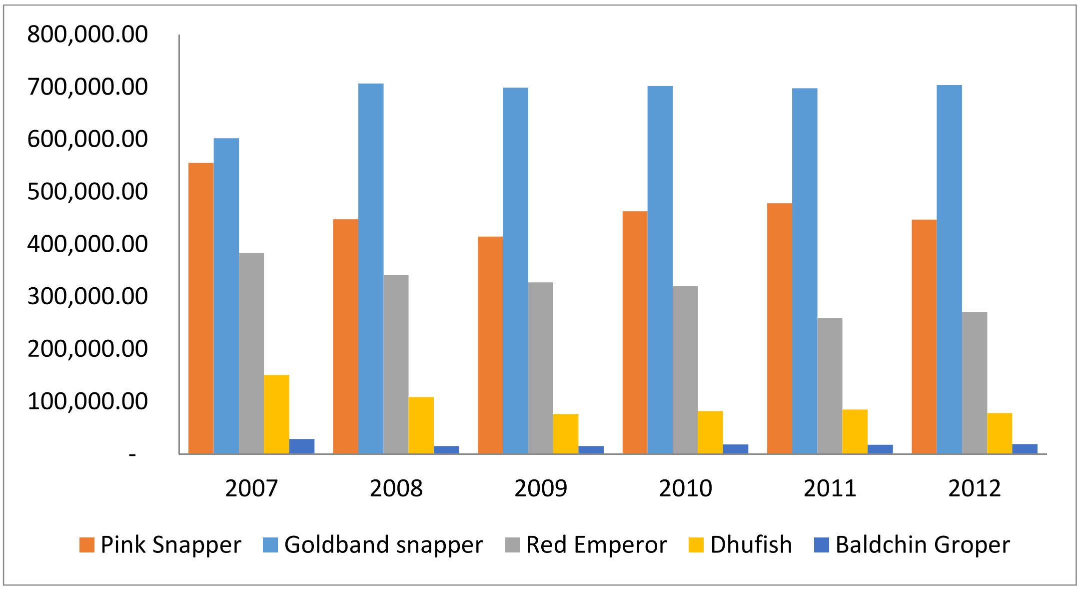
The seasonality of catch is evident for both Snapper and for red emperor.

Figure 37: Monthly WA Finfish Commercial Catch



Source: Department of Fisheries, Western Australia

Figure 38: Annual WA Finfish Commercial Catch

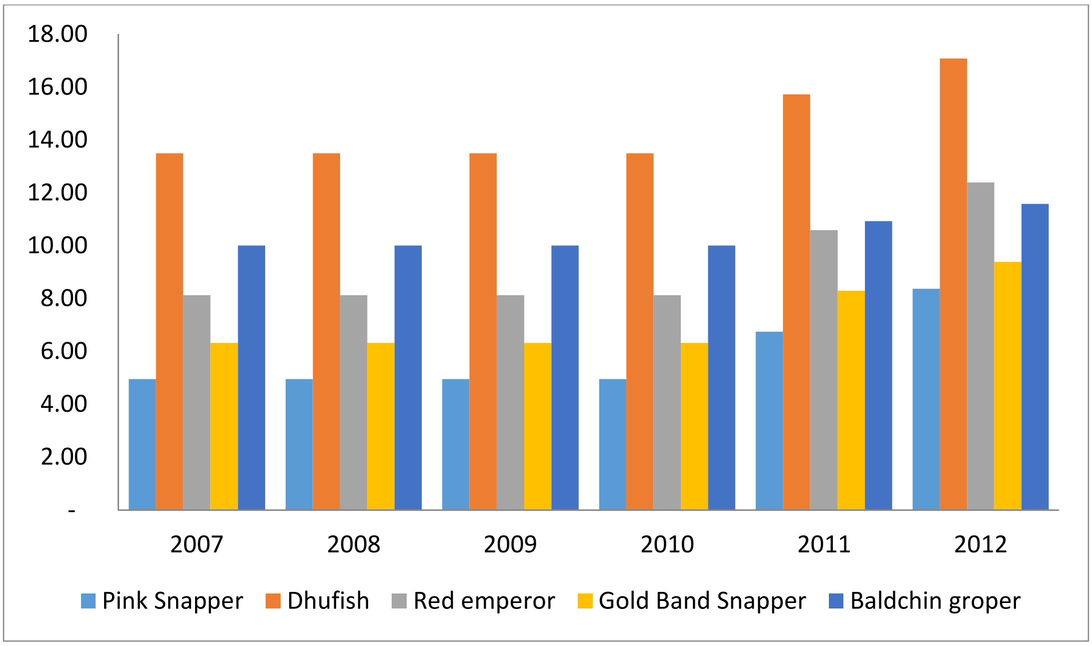


Source: Department of Fisheries, Western Australia

Prices

Commercially West Australian Dhufish commands significantly higher prices. Western Australian beach prices are estimated by the Department of Fisheries. The annual beach price is shown in Figure 39. The two snapper species have experienced higher prices in recent years (2011-2012) with Snapper achieving around $8.5/kg.

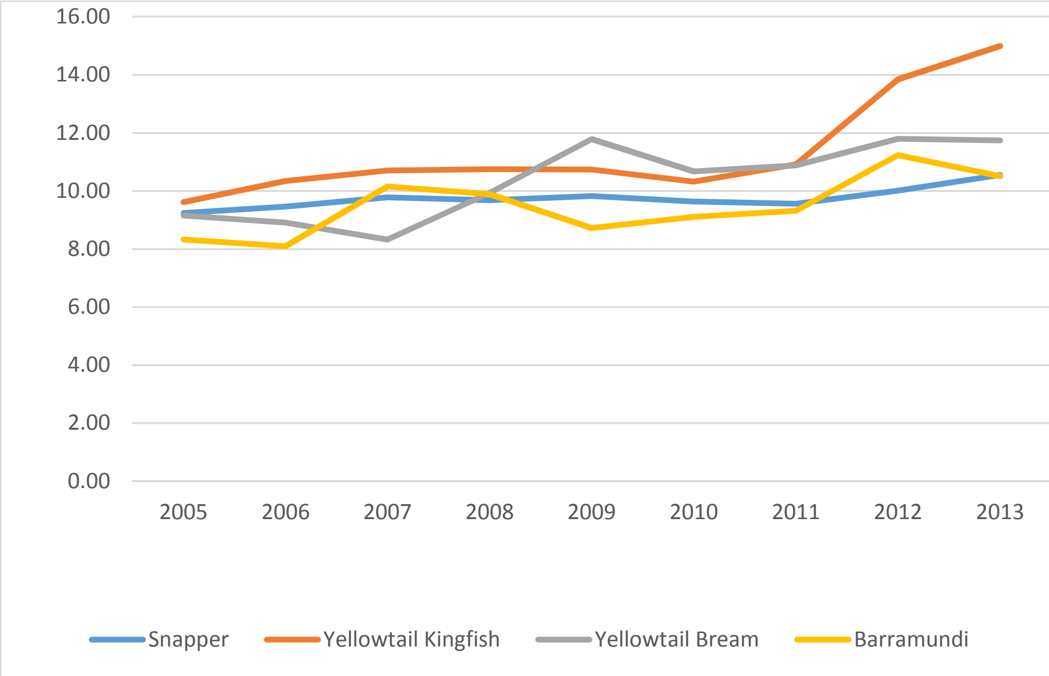
Figure 39: Beach Price for the WA Finfish Harvests



Source: Department of Fisheries, Western Australia

The snapper prices reported by the Sydney Fish Market are shown in Table 17. Snapper is defined generically but appears to be largely Goldband Snapper and Snapper.

Figure 40: Sydney Fish Market Auction Prices



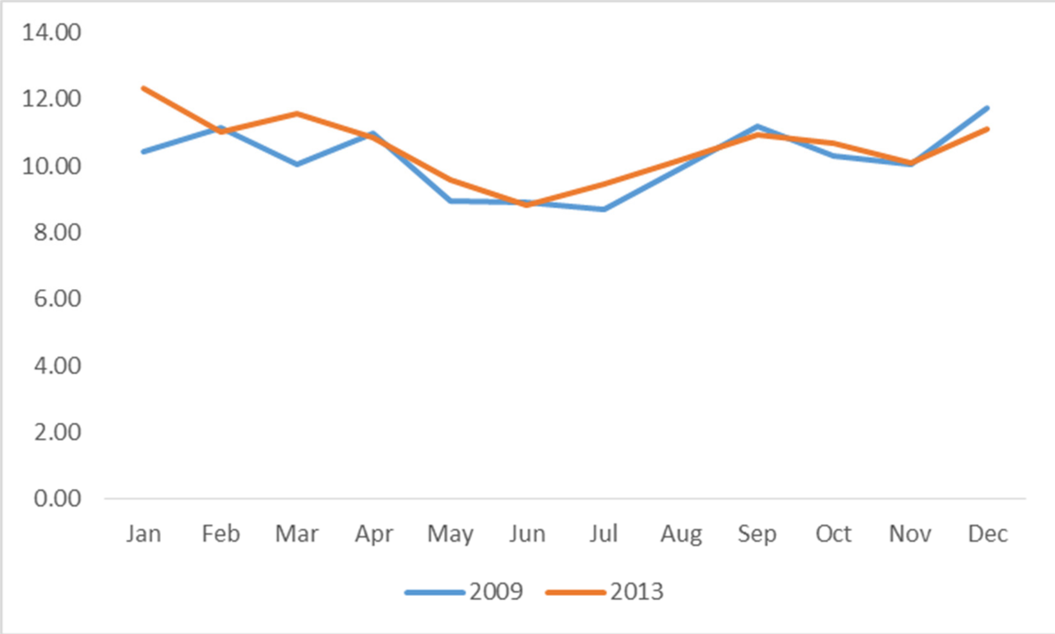
Source: Sydney Fish Market Annual Reports

Intra-year Snapper and Other Species Prices

The individual fishers fishing for Snapper also fish for other species, both opportunistically and deliberatively. They fish different fisheries where their preferred catch species can be taken moving between fisheries and areas as required to optimize catch and revenue and comply with harvest rules. For example, individual Snapper fishers will fish the Mid West and Kalbarri, but will also decamp to ocean off the Gascoyne and Pilbara coastline when conditions and expected catch warrant.

Figure 41 shows monthly average beach prices for Snapper for 2009 and 2013. This is before and after the recent policy change to wind back effort by reducing the hours of fishing entitlement. These are prices received by fishers fishing in the Mid West and Kalbarri regions. Fishers sell their Snapper catch in two broad ways. Some sell under contract to a major processor/wholesaler, while others utilise the fish markets and sell at auction. Although individual monthly prices vary across skippers under these arrangements, the annual average price is very close across all selling methods. This is to be expected given the relatively small size of the industry, the availability of information sharing, and the ability to arbitrage between the individual processor contracts and the markets at auction. The 2009 average is $10.19/kg and the 2013 average is $10.55/kg. The difference between 2009 and 2013 mean prices is statistically insignificant for this group of fishers.

Figure 41: Monthly Beach Prices for Snapper



Source: Data Supplied by individual northern inshore area fishers

Snapper Substitutes and Market Pricing

The indicative evidence suggest that the major fish species caught and sold locally in significant volumes, namely Snapper and Goldband Snapper, are close substitutes, with other prime fillets and whole fish – the various emperors, tropical snappers and West Australian Dhufish making up an extended list of substitutes. In addition, as noted in the following section, the identical NZ Snapper species is produced in volume, and can be readily imported into Australia and WA. NZ species, such as orange roughy and flounder, already have a substantial presence. The range offers consumers variety in their purchase of whole fish and fillets. Consumers are not locked into a narrow range of quality fish, and certainly not just Snapper. It also needs to be noted that consumers also have access to farmed fish imported from a variety of locations. These include basa fillets from Vietnam, which are widely available, and salmon, both from Australia and overseas.

At any given time therefore, Snapper fillets and whole fish products are subjected to an extensive array of competitor species available at different price and quality points.

This suggests that demand for Snapper will be price elastic as an individual species. This in turn means that the ability to raise price relative to other species is limited.

For a price elastic species, a reduced volume caught will not raise price sufficiently to raise revenue in the long run. There will be a long run price relationship that reflects the underlying position of Snapper in the market place. Although there may be short run movements away from this relationship, it will tend to be restored in the long run by adjustments of price for Snapper and for the other competing species.[44] In effect, we expect Snapper and other fish species prices to be cointegrated in the Western Australian market place.

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[44] The price elasticity also has implications for the potential effectiveness of generic advertising as discussed further below.

Consistent time series data on prices for finfish species are not sufficient to test market integration and price elasticity for individual species such as Snapper. However, there is no reason to believe that Australian and Western Australian consumers behave differently to consumers in other jurisdictions, and evidence from these sources is a valuable insight into the place of an individual species in the market place.

A distinction exists between fish as a whole, where the substitutes are other food protein sources such as red meat and chicken, and a single fish species where the closer substitutes are competing fish species offering similar eating and nutrition attributes.

Insofar as price elasticity of demand is concerned the general finding in the literature is that for fish as a group, demand is price inelastic (>-1) whilst for an individual species within the group it is elastic (<-1). Gallet (2009) reviews 168 fish demand studies in a meta-analysis and concludes that the best estimate of the own price demand elasticity is -.79 whilst for a species (salmon) it is -1.28. Asche et al (2007) found the demand for fish to be generally price inelastic. A review of food price and income elasticities in the UK by DEFRA (2012) estimates the short run own price elasticity of demand for fish to be -.78. Both blue fish and white fish had price inelastic demands.

The review by Asche and Bjorndal (1999) investigates the price elasticity of demand for fish and concludes that it price-elastic. Own price elasticities in range of –0.8 to –1.5 are indicated.

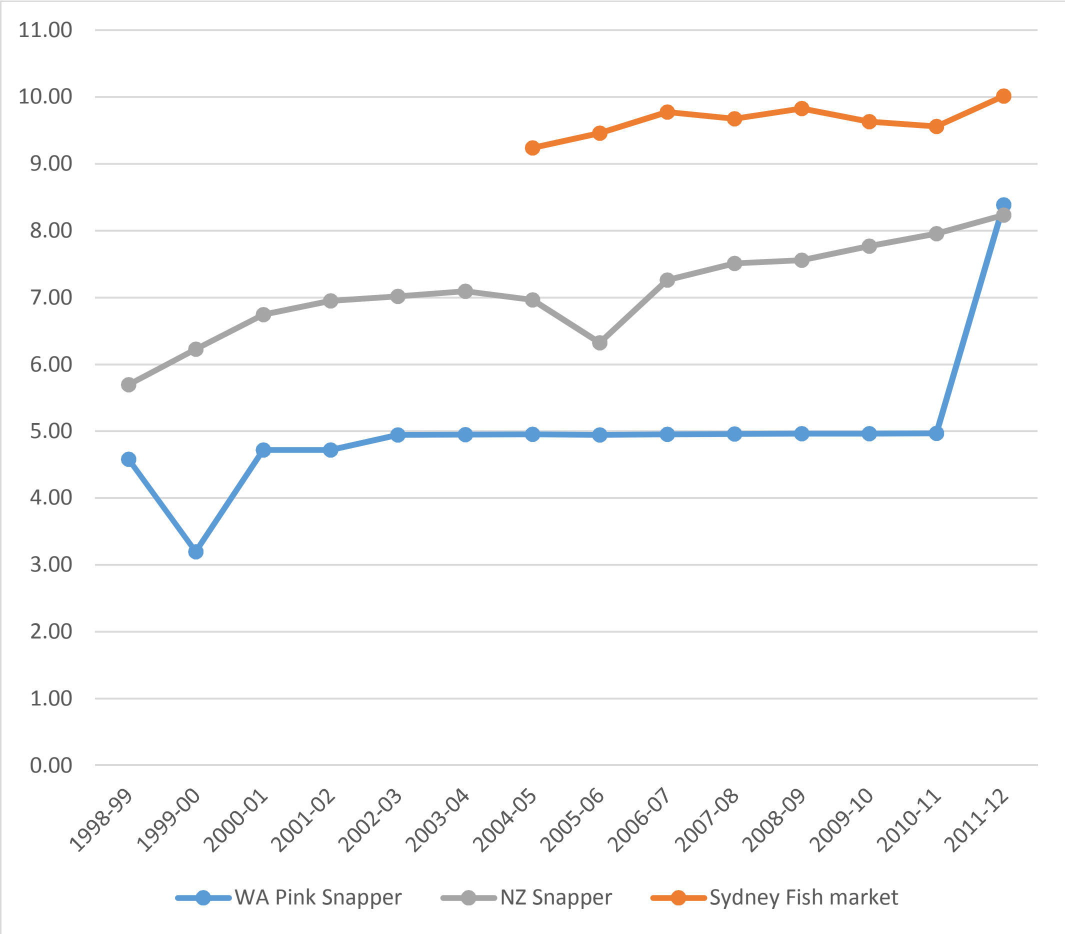
Application of Johansen cointegration (Asche et al. 2002) to the European whitefish market indicates that the different fish prices form a long-run equilibrium relationship. The evidence indicates an integrated EU whitefish market encompassing similar product forms made from different fish species. (Nielsen et al. 2009) found similar outcomes with market integration across fish species in Europe across both fresh and frozen fish. Relative prices across fresh species are found to be relatively stable leading to the conclusion that catch restrictions on one species will not 'compensate' fishers through higher market prices because integration limits such price increases as consumes shift to substitutes.

Exports and Imports

Interviews with processors indicated the potential for import competition. In addition to local competition from red emperor, and Goldband Snapper, imported fish also compete in the Western Australian market. In the case of Snapper, the most obvious potential import competition is Snapper from New Zealand. This is the same species (*Pagrus auratus)* and is exported in large volumes from New Zealand.

The price of Snapper in WA, at the Sydney Fish market and imported from New Zealand Snapper are shown in Figure 42 using annual data for the period 1998/99 to 2011/12. There appears to be a margin between the prices, except the most recent years when local Snapper prices have approximated NZ prices, although the WA Snapper price data is open to question as already noted above.

Figure 42: WA Snapper, NZ Snapper and Sydney Fish Market Snapper Prices



Source: Sydney Fish Markets Annual Reports, Department of Fisheries, Western Australia and NZ Harmonized Export Data

Modelling the supply Chain

Supply Chain Concepts Applied to the Snapper Fishery

Finfish produced in Western Australia comes from variety of fisheries, fishing methods and species. The supply path for each species varies according to the nature of the final product and the destination. For Snapper the final market is primarily Perth with the product form being whole fish (gutted) and fillets. Most Snapper goes to fishmongers and food service and only a small minority of the catch is sold to customers through the major supermarkets.

Firms can be involved in one or more activities. For example, some processors buy whole fish from fishers, process (fillet) and distribute fish to retailers, Sealanes is a firm that does this with Snapper. Some fishers organize processing but retain ownership of the fish and take responsibility for sales to consumers. Australia Bay operates trawlers out of Darwin, has Catalanos as its Perth based processor and delivers saddle tail snapper to Coles and Woolworths.

Figure 43: Schematic Supply Chain for WA Snapper

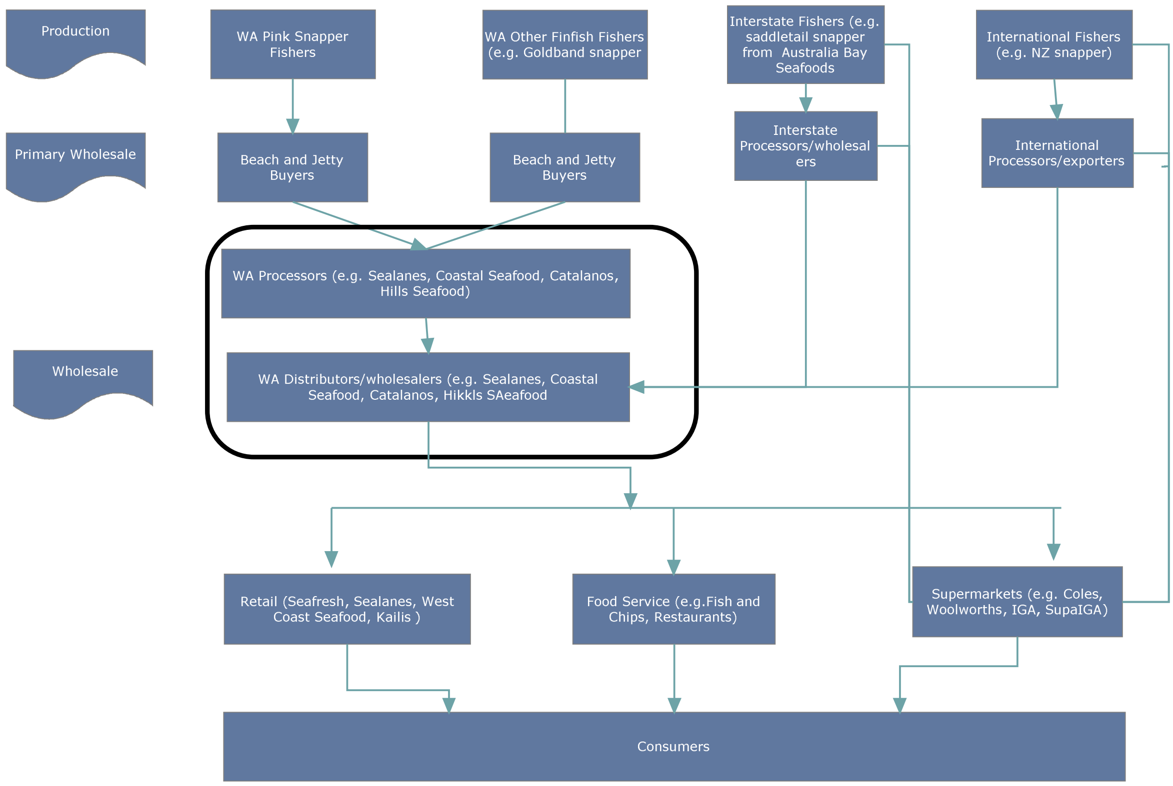


Figure 43 shows the nature of the supply chain reflecting the Snapper chain and competition from locally caught alternatives and imported alternatives to Snapper.

At each point in the chain, firms are driven to make a profit reflecting its cost of production and a margin.

The price increase from one channel to the next is the *price margin* or *mark-up*. Each fish processor who produces fish fillets must make enough on the subsequent sale of his or her product to pay for the whole fish, workers and managers, shipping costs, plant and equipment overhead; in addition, the firm must earn a reasonable return on investment.

The following analysis produces indicative margins analysis for Snapper and saddle tail snapper in the Perth market.

In thinking about the chain and margins along the chain, the analysis can work backward from retail to catching or forward from catching to retail. The following discussion works backwards but actual data is taken from selected points where information is known or estimable.

The reference species is Snapper. Suppose the retail market price, P*ret*, to the consumer for Snapper fillets is $59 per kg. Assume that this is an equilibrium price, at which demand equals supply. In the case of Snapper, the fishery is not managed by catch quota but with a mix of effort controls. The price in the market (including fillets at retail through to whole fish at the catching stage) is that which “clears” the supply brought to market in Perth in any given period. Margins will be higher in food service per kg than in retail sales of fillets to consumers through fish mongers.

$$P_{dist} = P_{ret}(1 + M_{ret})$$

If the wholesaler purchased fillets from a processor who filleted the Snapper, then the processor would receive a price reflected in the following mark-up equation.

$$P_{proc} = P_{dist} / (1 + M_{dist})$$

If the processor purchased a locally caught whole fish then the fisher would receive a price as follows.

$$P_{fisher} = P_{proc} / (1 + M_{proc})$$

The above is the price received by the fisher based on the product format of the sales of the processor. If the processor is paid per kg of fillets, P_{fisher} is the price to the producer per kg of fillets. The price for whole fish depends on the yield in transforming whole fish to fillets. To get the price of whole fish per kg multiply the P_{fisher} by yield as follows.

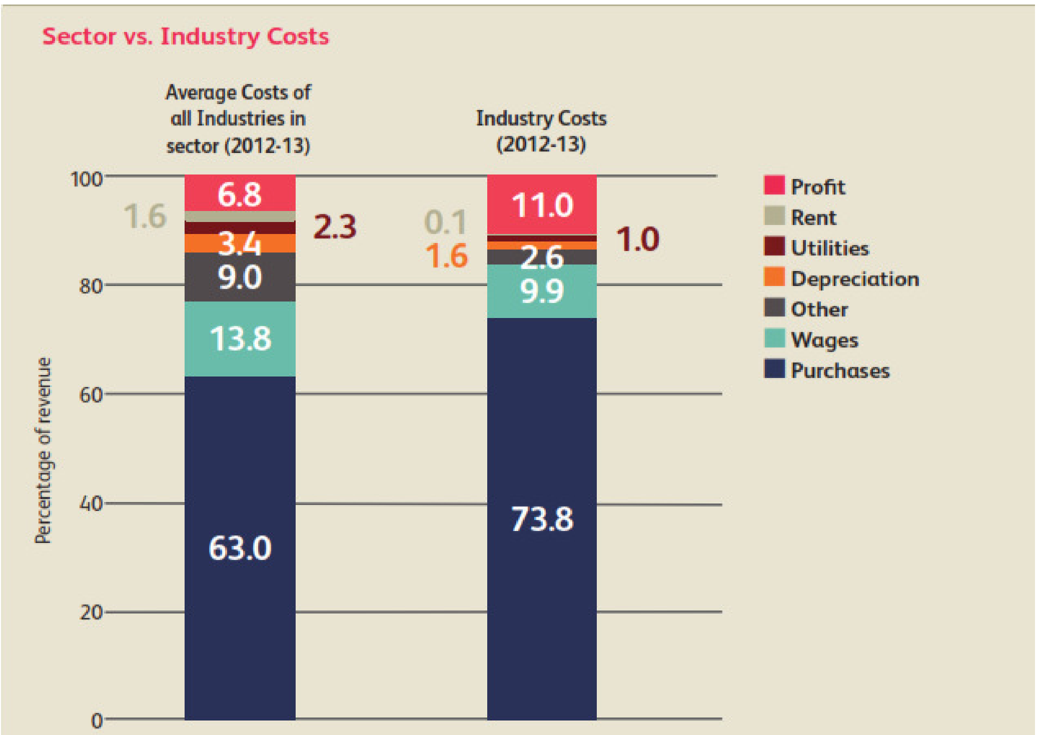
$$P_{fishwhole} = P_{fisher} . Yield$$

Applying the above logic the values in the Snapper supply chain can be assessed and compared to the values in the supply chain for competitive products.

Margins in Fish Processing and Retailing

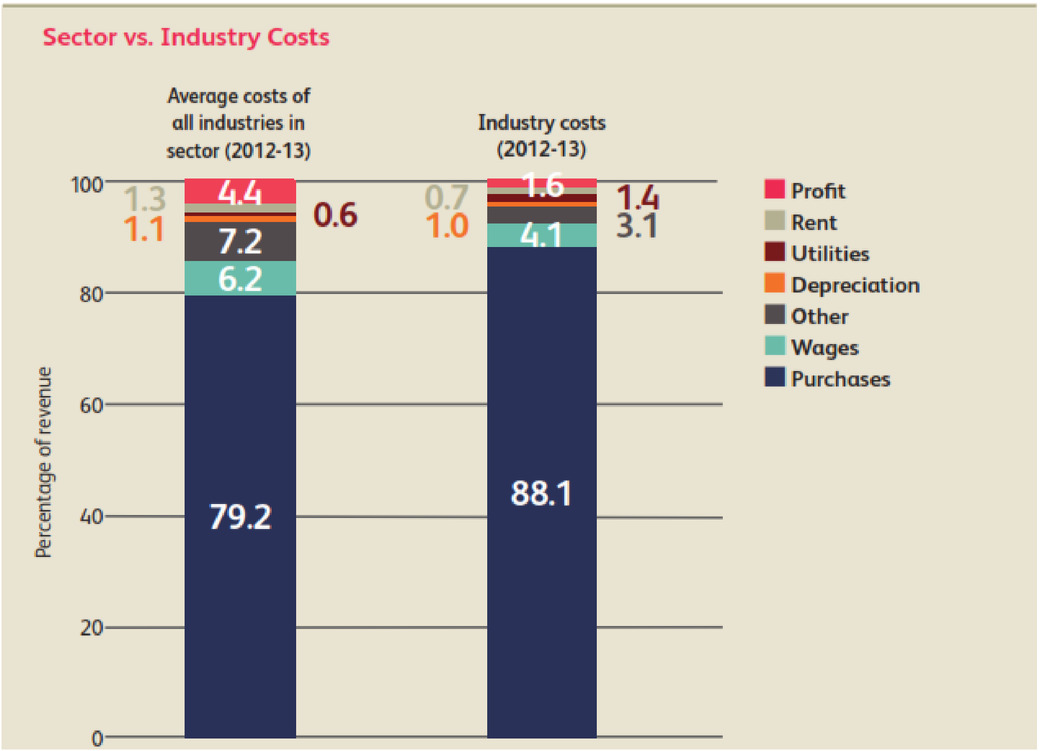
Margin analysis in fishing and processing is not plentiful in either Australia or elsewhere. At the industry level reports by IBISworld offer insights into the overall performance of seafood processing, wholesaling and retailing. These results are reported in Figure 44 and Figure 45.

Figure 44: Cost and Margin Composition for Seafood Processing



Source: IBISWorld. Industry Report C1120 Seafood Processing in Australia

Figure 45: Cost and Margin Composition for Seafood Wholesaling



Source: IBISWorld Industry Report F3604 Fish and Seafood Wholesaling in Australia

Results From supply Chain Analysis

The catch and associated beach prices are seasonal. The monthly fluctuation in catch over the year was shown in Figure 32. During the peak harvest, monthly catch volume for Snapper is between two and five times the low harvest monthly catch.

The retail price for fillets and whole fish can be expected to vary over the year to reflect this pattern of variation in Snapper abundance and harvests. Using the basic data on beach price, retail price data for whole fish and fillets and indicative margins at each part of the chain an indicative supply chain explanation for the price structure of Snapper, West Australian Dhufish and Goldband Snapper has been determined for the peak and off peak prices.

Margins data is known primarily as a percentage from sources such as IBISworld and the model presented above uses margin in this form. However, while the literature suggests that this is a reasonable way to characterize the supply chain, there is evidence from agriculture that the absolute margin may remain fixed. In particular, where there is intra-year variability, the margins may stay the same in absolute value over the year because the actual costs of processing, wholesaling and retailing per unit do not change and as one product or species experiences declining volumes another is processed in its place. For example, if during months when Snapper volumes are lower and goldband or other finfish volumes are higher, processors, wholesalers and retailers may be able to sustain volumes and hence have similar costs at each link in the chain. Table 21 shows indicative margins and prices for Snapper for peak demand periods when prices are highest. The table is an application of the model presented above. It reconciles the beach prices paid to fishers with indicative retail prices and price indicators from wholesalers at time of selling fish products to retail. Table 22 presents a similar calculation for a high supply period. As expected the margins are lower in the high supply period and these margins best explain the retail and beach price relationship using the suggested model structure.

The margins that are calculated are very close to those estimated by IBISWorld for fish processing and wholesaling in Australia. They are also consistent with the value added ratios and margins implied in Nath et al (2011) in their analysis of value added along a finfish trawl harvest supply chain.

Table 21: Indicative Margins and Prices for Snapper at Low Supply Period

Fillets	Recovery	Mark-up	Price	$margin
Pret		0.33	$ 60.00	$ 14.89
Pdist		0.14	$ 45.11	$ 5.41
Pproc		0.32	$ 39.70	$ 9.53
Pfish	0.35		$ 30.17	$ 19.61
Pfish			$ 10.56	
Whole Fish		Mark-up	Price	$margin
Pret		0.33	$ 22.86	$ 5.67
Pdist		0.14	$ 17.19	$ 2.06
Pproc		0.32	$ 15.12	$ 3.63
Pfish	0.87		$ 11.49	$ 1.49
Pfish			$ 10.00	

Table 22: Indicative Margins and Prices for Snapper at High Supply Period

		Mark-up	Price	$margin
Pret		0.33	$ 42.61	$ 10.57
Pdist		0.14	$ 32.04	$ 3.84
Pproc		0.32	$ 28.20	$ 6.77
Pfish		0.35	$ 21.43	$ 13.93
Pfish			$ 7.50	
		Mark-up	Price	$margin
Pret		0.33	$ 17.14	$ 4.25
Pdist		0.14	$ 12.89	$ 1.55
Pproc		0.32	$ 11.34	$ 2.72
Pfish		0.87	$ 8.62	$ 1.12
Pfish			$ 7.50	

Generic advertising and returns to fishers

Generic advertising is a feature of many agricultural industries, both in Australia and overseas. Overseas empirical studies into its impact have primarily focused on the best developed schemes relating to beef, pork, milk, cheese and eggs. Fluid milk and meat products dominate these studies. In seeking to understand the impact of generic advertising, the focus has typically been to understand whether the advertising has a positive effect on demand. This is usually tested by estimating demand equations that include advertising expenditure or dummy variables in addition to normal demand variables - the price of the product in question, the price of subtitles and real income. Published studies of generic demand of fish are limited.

Generic advertising is typically funded by producer based levies and focuses on promoting the generic product – meat, eggs and fish. For example, the generic advertising of eggs typically promotes egg consumption not particular types of eggs produced. There are two reasons for this.

First generic advertising of the product promote the cause of all producers and is aimed at shifting the demand curve to the right at the expense of competing generic products. Promoting a particular subset within a generic group (e.g. Snapper) runs the risk that the promotion would simply cannibalize the other products in the generic group (e.g. fish) because products within the group (e.g. types of eggs, or lamb or fish) are closer substitutes for products inside the group than they are for products in other food groups.

Second, in some cases there is a health message associated with generic advertising. For example, the promotion by AECL of eggs in Australia coincided with the award of the National Heart Tick to eggs. The promotion of fish is usually about getting consumers to switch to fish and away from other foods as part of encouraging a healthier diet. The important aspect about generic advertising in this sense is that it is independent of the particular producer and/or location (e.g. state).[45]

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[45] A quality attribute such as sustainability might also be used as a platform for undertaking generic advertising. MSC accreditation is an example. The Western Rocklobster fishery is already MSC accredited and other WA managed fisheries are to be the subjected to independent accreditation. However, finish is sold locally and if the quality of WA management, compared say to imports, is

There has always been debate about the impact of generic promotion on both demand and on producer incomes. The former is essentially the question of the impact of generic promotion in shifting the demand curve to the right. The second is the question of the net impact that any such shift in demand has on produces given that the advertising/promotion cost have typically been funded by a production levy that increases producer costs.

Consider a levy applied to the harvest of fish on a per kg basis and used to fund the promotion of fish to consumers.

The combined demand and supply curve shifts associated with the imposition and expenditure of the levy lead to changes in market prices and quantities, which affect the net return received by fishers. Being competitive price takers, fishers will gain from the program only if the net price they receive increases.

Put simply, after allowing for responses of market prices and quantities, producer returns will increase net returns if, and only if, the demand expansion effect of generic advertising increases the producer price received by more than the cost increasing impact of that portion of the levy finally borne by producers (see Figure 47 and Figure 48).

Freebairn et. al. (2004) developed a simple model to determine the general conditions under which a generic advertising program will increase the net return to producers. They conclude that this would occur if the following pre-conditions were met:

1. the advertising program succeeds in increasing the quantity of product sold at retail
2. these extra sales are reflected in higher producer prices, and
3. producers can supply the extra sales only through production with a higher marginal cost.

An important further condition is that generic advertising does not spill over to imported product. In the case of a product like shell eggs in Australia, the domestic market is protected by various quarantine restrictions so any demand boost is likely to impact Australian producers. However, for fish, there are significant imports, so a shift in the Australian consumers' demand for fish is likely to spill over to these imports. This issue is also relevant and potentially more so, if the fish products being promoted are state based harvests. In this case, imports from other states may now benefit from the spill over effects of the generic advertising.

Simple demand and supply analysis can be used to illustrate the issues involved assessing the impact of generic advertising.

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already acknowledged then obtaining a further price premium based on MSC may be difficult. This may be also true in export markets. Anecdotal evidence suggests there been little (if any) price premium attributable to such accreditation for lobster and the price data analysed in this report does not show any detectable impact on prices.

Figure 46: Impact of a Levy on Production Costs and Prices

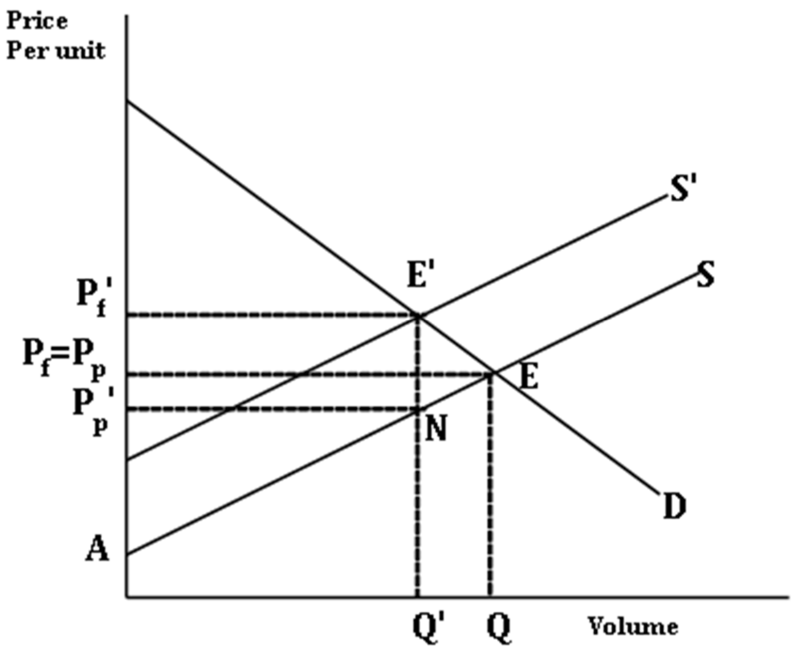


Figure 46 illustrates the effect on market supply and price of the imposition of the production levy used to fund advertising. In this figure, the demand curve, D, which is the producer demand curve for fish derived from the retail demand for fish does not shift because only the levy is included.

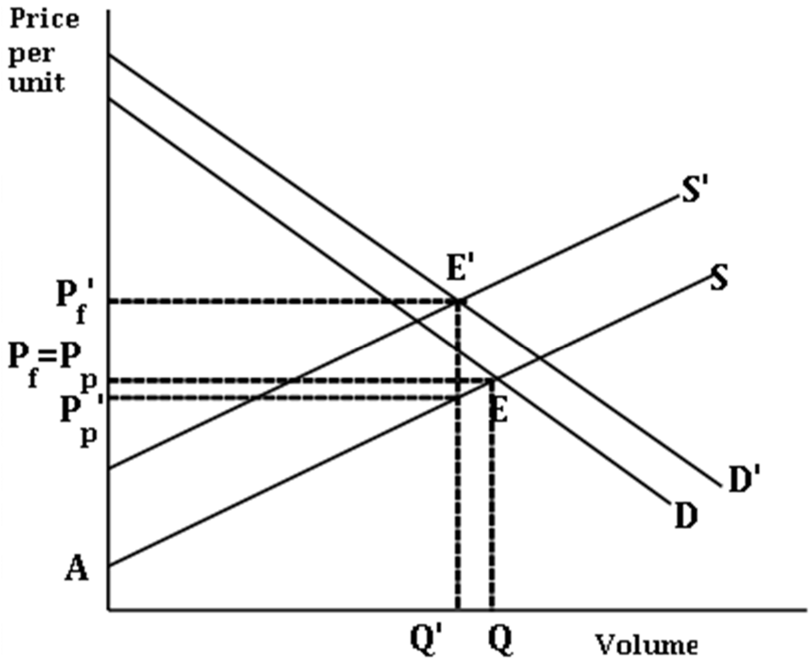
Looking at the levy in isolation, the supply curve shifts upwards from S to S', and the equilibrium quantity of output falls from Q to Q'. The produce price, P_f, shifts up from to P_f'. of course with only the levy increasing costs, the producer is worse off because the net producer price falls from P_p to P_p',(= P_f' – L, where L is the levy per unit of production).

If the generic advertising program shifted out the demand curve in Figure 46 just enough to get market output back from Q' to Q, the levy would break-even. Beyond this, some net gain would arise.

Generic advertising levies are introduced for the sole purpose of promotion. Therefore, we can consider the case where you have either no levy and no advertising or a levy with advertising equal to the value of the levy.

Figure 47 illustrates the case where the levy does not shift demand enough and Figure 48 the case where the demand shift is more than breakeven.

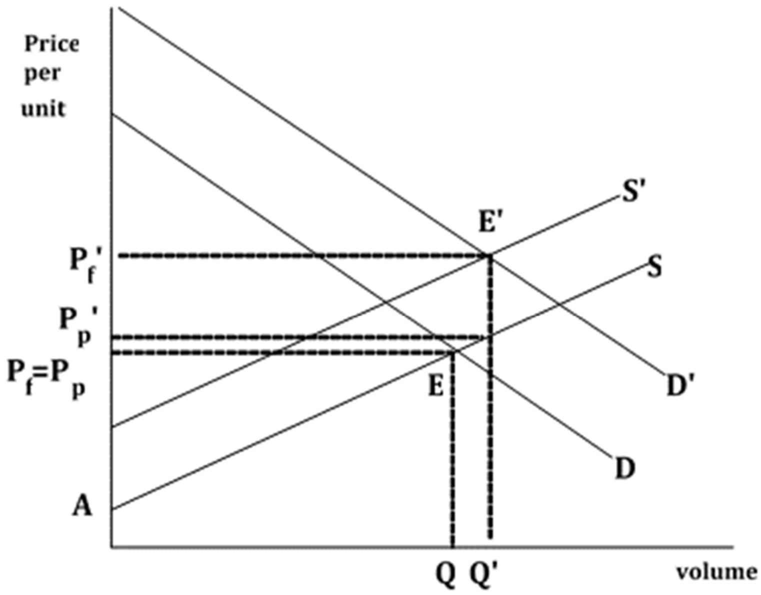
Figure 47: Demand Shift Insufficient to Justify Advertising Levy



In Figure 47, relative to no levy and no advertising, the impact of generic advertising on the producer price is less than the impact of the levy. As result, the net effect of the levy and generic advertising combined is to reduce both the quantity of output (from Q to Q') and net producer price (from P_p to P_p').

Figure 48 depicts the case where generic advertising more than offsets the impact of the levy on producer price. Thus, relative to the counterfactual scenario of no levy and no advertising, the combined impact of generic advertising and producer levy for this case is to increase producer welfare by increasing both the quantity of output (from Q to Q') and net producer price (from P_p to P_p'). Note that the corresponding increase in producer price (from P_f to P_f') will be larger than the increase in net producer price by the amount of the levy.

Figure 48: Demand Shift Justifies Advertising Levy



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A simple simulation of the demand increase requirements relative to the levy can be achieved using the formula in Freebairn et. al. (2004) which calculates the minimum increase in sales volume required for a generic advertising program, funded by a producer levy, to increase producer returns.

Applied to fish markets, this simple model assumes competitive behaviour in the post-harvest processing and retailing sectors of the industry. The formula is of the form:

$$((dQ \,/\, dA))/\, Q \;>\; E\;(L \,/\, P)$$

where Q is retail fish sales volumes, A is advertising, E is the absolute value of the own price elasticity of demand, L is the levy per kg of fish harvested, P is the retail price per kg of fish, and d is the symbol for derivative or small change.

The left hand term (dQ / dA)/ Q is the minimum required increase in fish sales due to advertising. It is the increase in sales, the term dQ/dA, as a proportion of current sales, Q. The right hand term E.(L/P) is the own price elasticity of retail demand for fish E (the percentage change in fish sold divided by the percentage change in the retail price), times the levy as a proportion of the retail price, the term L/P. The more price elastic is retail demand for fish and the lower is the price of fish at retail the greater has to be the effect of advertising to increase sales if fishers are to gain.

This formula can be used to simulate the advertising response required under plausible assumptions about price elasticity, retail price and volume.

Table 23: Percent Increase in Sales Required for Combinations of Elasticity and Levy with Price =$40/kg

Levy rate	Absolute value of own price elasticity					
	-0.5	-0.75	-1	-1.25	-1.5	-1.75
10	0.13%	0.19%	0.25%	0.31%	0.38%	0.44%
20	0.25%	0.38%	0.50%	0.63%	0.75%	0.88%
30	0.38%	0.56%	0.75%	0.94%	1.13%	1.31%

Table 24: Percent Increase in Sales Required for Combinations of Price Elasticity and Levy with Price = $60/kg

Levy rate	Absolute value of own price elasticity					
	-0.5	-0.75	-1	-1.25	-1.5	-1.75
10	0.08%	0.13%	0.17%	0.21%	0.25%	0.29%
20	0.17%	0.25%	0.33%	0.42%	0.50%	0.58%
30	0.25%	0.38%	0.50%	0.63%	0.75%	0.88%

Evidence on Generic Advertising and Price Elasticity of demand

The tables above cover a range of price elasticities. On balance for an individual species a price elastic demand (<-1) is suggested.

Evidence on both the price elasticity of demand and the impact of generic advertising is limited for fish products.

As previously noted, the general finding in the literature is that for fish as a group, demand is >-1 whilst for an individual species within the group it is <-1. Gallet (2009) reviews 168 fish demand studies in a meta-analysis and concludes that the best estimate of the own price demand elasticity is -.79 whilst for a species (salmon) it is -1.28. Asche etc. al (2007) find the demand for fish to be generally price inelastic.

A review of food price and income elasticities in the UK by DEFRA (2012) estimates the short run own price elasticity of demand for fish to be -.78. Both blue fish and white fish had price inelastic demands.

Generic advertising has received little attention for fish compared to the work done on generic advertising and the demand for meat, eggs and milk.

The work that has been done has essentially focused on farmed species like salmon. For example, Kinnucan and Myrland (2001) find hat Norwegian promotion shifts the demand curve to the right for exports from Norway and is welfare enhancing. Myrland, et al (2004) find that Norwegian seafood promotion in Japan has a positive impact on demand but not does generate a large return to producers.

This is consistent with the model presented above which shows that to get a benefit to producers you need a positive supply response. A positive supply response when demand shifts to the right is possible in farmed product but not necessarily possible for wild caught fish where management regimes may fix or limit catch and, depending on the stock status, may be attempting to reduce catch as is the case in the WC demersal scalefish fishery.

Fish is a normal good. The demand curve for fish will shift to the right as real incomes rise. Although the evidence is simply not available to be certain, a reasonable expectation might be that high quality, well presented and environmentally well managed fish such as Snapper might have higher income elasticity than fish in aggregate. In this event, product quality is an important element in securing premium prices into the future and may contribute to increasing spikes relative to other fish species, subject to competition from aquaculture and imports.

The evidence presented above does not suggest that rearrangement of the industry post-harvest is an area where fisher returns can be enhanced to any great degree. Snapper and related close substitute fish such as West Australian Dhufish and Goldband Snapper are already priced at premium prices. As such, they primarily enter the market through specialised fish retailers, fish and chip shops and restaurants. Priced in this way they are above the price point at which major supermarket's price fish to make it competitive with red and white meat substitutes. Fish like Saddletail Snapper satisfy this need.

The processing and retail sectors appear to be contestable based on the number of firms in operation and the number of firms that have the capacity to switch to processing and wholesaling/retailing fish species such as Snapper if incumbents were thought to be making super normal profits.

Generic advertising of fish offers a potential to shift demand from substitutes products like red meat to fish. The regiment here is that health gains are possible by making such a switch. As such, the subject of the generic promotion is fish not a particular type of fish. A key to getting greater returns for fishers Siva generic promotion is a positive supply response. This is more likely to be possible in aquaculture. Hence, the evidence of generic promotion success has mostly been assessed in relation to salmon.

Snapper and the other major species associated with the West Coast Demersal Scalefish Fishery are in limited supply and likely to be subject to even tighter harvest limits in future (see below). Moreover, the available evidence suggests that the availability of substitutes for Snapper is such that commercial fishers are not likely to be compensated for harvest restrictions through higher prices for the restricted catch.

The potential to increase fishers' net returns resides mainly in the area of reducing harvest costs. This in turn is inherently connected to management of the biomass and the regulatory regime used to achieve harvest/biomass objectives. The implications for harvest efficiency within the existing management regime are assessed in the next section.

Management of the Fishery

Management History

Until mid-2000, there was open-access to the demersal scalefish in the West Coast fishery[46] and into the adjoining Gascoyne region. At the time, fishing in these waters was managed primarily through a mix of control measures including size limits, some gear limits and closed seasons for commercial fishing for some species and also recreational fishers, whilst size limits, and catch (bag and boat) limits, some temporal and area closures applied to recreational fishers (including charter operations).

The open access meant that there was potential, particularly in the West Coast region of the fishery, for up to 1,250 licensed commercial fishing boats to engage in 'wetline' activities.

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46 Whilst the Southern and West Coast Demersal Gillnet and Demersal Longline Fisheries, where scalefish is an important component of the catch in the West Coast, had been under formal management arrangements since 1988 and 1997 respectively, there were no other constraint on entry for other method based demersal fishing, e.g. hand lines, drop lines and troll lines.

The rapidly growing population, rising living standards with accompanying rapid growth in recreational boat (larger and faster) numbers, and improving infrastructure (roads, port facilities) also meant the potential for increasing and more widely spread recreational fishing effort along the west coast into the Gascoyne region.

In May 2007, following a three year review of commercial wetline fishing, the Government introduced a two stage strategy to contain commercial catch and to reduce latent commercial fishing effort. The first stage, introduced in late 2007, established an Interim Managed Fishery effective from 1 January 2008 with entry permits that limited access to the West Coast Demersal Scalefish Fishery from a potential 1,250 boats to 61 operators. Of this reduced number, the number with access to each of three of the four defined inshore 'areas' (or zones) of the fishery, following the November 2007 announcement of the Metropolitan Area closure[47] to commercial demersal scalefish fishing, was also limited[48].

The second announced phase, which commenced on 1 January 2009, introduced numerous indirect controls built around maximum effort limits (fishing time 'capacities') to contain the demersal scalefish commercial take from the West Coast fishery[49] with no direct controls over the quantum of take. This stage involved a scheme allocating entitlement to permits (in the form of units that provide entitlement expressed in fishing hours) and allowed for the transferability of both entry permits and units of entitlement.

These strategies were intended to allow the commercial demersal scalefish catch in the fishery to remain static, whilst management objectives and the future harvest strategy (including new management arrangements for the recreational sector) were determined and implemented.

The stock assessment at that time was indicating fish stock mortality rates for the 'key indicator' species [50](Baldchin Groper, Snapper and West Australian Dhufish) materially higher than the internationally recognized reference rates for this type of fishery; heightening concerns about the sustainability of demersal scalefish stocks in the fishery. The subsequently determined and current management objective is to restore sustainability of demersal scalefish stocks and to return the stock mortality rates for the 'key' indicator species to levels more consistent with the internationally 'accepted' reference rates.

The stock assessment at the time (2009) confirmed an earlier finding that a reduction in catch and fishing effort of at least 50% by both the commercial and recreational (including charter) sectors was needed to allow stocks to recover given time (which reportedly could take up to 10 years given the biological characteristics of the 'indicator' species). The harvest strategy to achieve this objective relied on tightening the then existing array of indirect controls for both the commercial and recreational sectors, although with no explicit direct controls of the quantum of 'aggregate' take by either sector.

The key elements of this strategy, included:

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[47] This closure also applied to boats with the West Coast Demersal Gillnet and Demersal Longline permits where this fishery overlapped waters in the northern part of the Metropolitan area of the West coast Demersal Scalefish Fishery.

[48] The number of permits for each of the inshore areas is limited to 35 in the Kalbarri 'area, 55 in the Mid-West and 11 in the South West areas.

[49] The overlapping Southern and West Coast Demersal Gillnet and Demersal Longline Fisheries had previously undergone a number of changes designed reduce effort by around 40% because of concerns about the sustainability of key shark stocks. These changes had the effect of reducing commercial demersal catches in these fisheries on the West Coast.

[50] These species were reportedly chosen because they are caught insubstantial numbers and because of their biological characteristics (longevity and slow growing and reaching sexual maturity) which apparently together they are likely to show signs of too much fishing before other species.

- a 50% reduction to 'capacities' (allowed fishing time) in each of the respective commercial fishing 'areas' of the fishery (and factored into the determination of the respective 'capacities' and the unit value of inshore area entitlements for the commercial fishing permits) for the 2009 licensing year,
- a reduction to multi-species bag and boats limits in the recreational sector,
- an increase size limits and gear restrictions such as an increase in the legal minimum size for Snapper south of Lancelin from 45cm to 50cm in 2009; with
- a subsequent demersal scalefish stock assessment in 4 years (2014).

A $20 'recreational fishing from boat license' fee was also introduced in the 2009 package of measures. As recreational fishing from boats is a popular and growing leisure activity in Western Australia, its inclusion was seen as having potentially an added 'dampening' effect on the level of recreational effort that may have occurred otherwise.

The experience in the Gascoyne region exhibited similar potential pressures for demersal scalefish stock in the region to be overfished. This fishery historically focused on Snapper during the winter months but also caught a range of demersal species.[51] A Snapper (season) quota scheme from the Shark Bay Snapper Managed Fishery had been implemented as early as 1988 because of declining stocks with a full year quota introduced in 2001.. In addition, closures in certain waters in inner areas of Shark Bay to recreational Snapper fishing had been introduced.

These pressures were mounting in the Gascoyne Region from increasing commercial activity to supply expanding domestic markets and the expanding recreational effort. The latter has been boosted in more recently by the growth in local remunerative employment associated with surrounding mining and offshore oil and gas developments.

Increasing concerns over the impact these pressures were having on sustainability of the demersal scalefish stocks in the Gascoyne ultimately lead the then Government, in October 2010, to introduce the Gascoyne Demersal Scalefish Management plan to take effect from 1 November 2010. This Plan, which incorporated the pre-existing Snapper catch quota system from the Shark Bay Snapper Managed Fishery, continued a Snapper quota system combined with indirect (effort) controls in the form fishing time and gear restrictions.

Current Management Arrangements

The key features of the current management arrangements operating in coastal waters from the lower south west into the Gascoyne and applying to demersal scalefish fishing are outlined in Table 25 below.

Commercial fishing is managed under a various method-controlled based Management Plans which apply in explicitly defined areas of these coastal waters, and, under certain Plans (e.g. West Coast Demersal Scalefish Interim Managed Fishery), sub-sets of those waters within the fishery. Recreational sector's (including charter operators) use, on the other hand, is managed within coastal waters falling within the defined Bioregional areas of ocean with typically no sub-sets of those waters. The respective ocean boundaries for these competing resource user sectors are not matching boundaries.

Table 25 shows the key elements of the commercial fishing management arrangements. The recreational management rules have been merged into Table 'items' as appropriate despite the

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[51] These included Goldband Snapper, rosy snapper, ruby snapper, red emperor, spangled emperor, redthroat emperor, cods, pearl perch, mulloway, amberjack and trevallies.

boundary difference. However, its contents should be carefully interpreted with this distinction in mind.

Table 25: West Coast Demersal Scalefish Managed Fishery Management Arrangements

Key Features	WC Demersal Scalefish Fishery	Overlapping and Adjoining WC Demersal Fisheries		
		WC Demersal Gillnet & Demersal Longline Fishery	**SC Demersal Gillnet & Demersal Longline Fishery (Zone 1)**	**Gascoyne Demersal Scalefish Fishery**
1. Nature of Fishery	Mixed, mobile demersal scalefish species fishery of moderate to low market values. Catch sold predominately on local WA markets.	Mobile species (shark with a valued scalefish component) of low to moderate unit market values. Catch sold mostly on local WA markets.	Mobile species (shark with a valued scalefish component) of low to moderate unit market values. Catch sold mainly on WA markets.	Snapper and demersal scalefish fishery of moderate to low market values. Catch sold predominately on local WA markets.
2. Location of Fishery	WA coastal water out to the AFZ boundary from 26° 30′ south latitude, south to the intersection with 115° 30′ east longitude	WA coastal waters off the west coast between 26° south latitude and 33°south latitude	Zone 1 covers WA coastal waters between 33° south latitude and 116°30.00′ south longitude	Waters of the Indian Ocean and Shark Bay between latitudes 23°07.30′ and 26°30′ south.
3. Stock Status and Assessment	**Fish status** Stock Level-recovering Commercial Fishing Level-not sustainable (Snapper only) Recreational fishing level –not sustainable (Snapper and Baldchin Groper only)	For both of these commercial fisheries insofar as the part that relates to demersal scalefish component, the fish status and stock assessment are encompassed by those for WC Demersal Scalefish fishery.		**Fish Status** Stock Level-acceptable Fishing Level-acceptable **Stock Assessment** relies on catch and effort data with a focus on selected indicator species (3 inshore with 2 for offshore) using

Key Features	WC Demersal Scalefish Fishery	Overlapping and Adjoining WC Demersal Fisheries		
		WC Demersal Gillnet & Demersal Longline Fishery	**SC Demersal Gillnet & Demersal Longline Fishery (Zone 1)**	**Gascoyne Demersal Scalefish Fishery**
	Stock assessments rely on annual catch & effort data and a periodic basic mortality and spawning rate model for key indicator species.[1]			a risk-based approach based on relative vulnerability of the species/stock to fishing activity.
4. Harvest Strategy	To reduce 2005/06 commercial demersal scalefish catch by at least 50% aimed at restoring mortality rates for 'key indicator' species to a level closer to internationally accepted 'benchmark' levels for this type of fishery.	For both these commercial fisheries, the targeted catch reduction for that part of catch relating to demersal scalefish is the same as the WC Demersal Scalefish fishery, i.e. 50% of the 2005/06 level.		To ensure sustainable use of the fish resource consistent with optimizing economic and social benefits
5. Season/Licensing Year	12 months commencing 1 January	12 months commencing 1 June	12 months commencing 1 June	12 months commencing 1 September

Key Features	WC Demersal Scalefish Fishery	Overlapping and Adjoining WC Demersal Fisheries		
		WC Demersal Gillnet & Demersal Longline Fishery	**SC Demersal Gillnet & Demersal Longline Fishery (Zone 1)**	**Gascoyne Demersal Scalefish Fishery**
6. Reduced Catch Target	**Commercial Fishing** All Scalefish 450t Demersal Suite 408t Dhufish 72t Snapper 120t Baldchin Groper 17t **Recreational (+Charter)** Demersal Suite 250t[2] Dhufish 126t Snapper 37t Baldchin Groper 33t	**Commercial Fishing** Demersal Species 42 t Dhufish 10t Snapper 6t Balchin Groper 2t Recreational catch targets in these fisheries are included in those for the WC Demersal Scalefish.		**Commercial** ('whole weight'): Catch Targets: Snapper-277t Goldband Snapper-50-120t Landing (season 2012) Total-389t Snapper-235t Goldband Snapper-64 t Spangled Emperor-4t **Recreational (incl. Charter)** Snapper-41t Goldband Snapper-18t Spangled Emperor-40t
7. Resource Sharing Targets	Proportional catch share guidelines[8] for the use to the West Coast Demersal Scalefish Resource:			**No formally determined resource sharing targets**

Key Features	WC Demersal Scalefish Fishery	Overlapping and Adjoining WC Demersal Fisheries		
		WC Demersal Gillnet & Demersal Longline Fishery	**SC Demersal Gillnet & Demersal Longline Fishery (Zone 1)**	**Gascoyne Demersal Scalefish Fishery**
	All Demersal 64% commercial 36% Recreational (+Charter) Dhufish 40% Commercial 60% Recreational (+Charter) Snapper 80% Commercial 20% Recreation (+ Charter) Balchin Groper 35% Commercial 65% Recreational (+ Charter)			
8.Direct Controls				
8.1 Entry Controls	**Commercial Fishing** Limited entry commercial fishery with 59 (?) issued permits in the 2014 licensing year. Permits have units of entitlement (time) to fish in 3 of the 4 'inshore' areas open to commercial fishing:	**Commercial Fishing** Limited entry commercial fishery with 24 issued permits in the 2013-2014 licensing year. Permits specify gear/time units of entitlement to fish. [7]	**Commercial Fishing** Limited entry commercial fishery with 20 issued permits in the 2013-2014 licensing year. Permits specify gear/time units of entitlement to fish.[7]	**Commercial Fishing** Limited entry commercial fishery with 55 issued MFLs in the 2013-14 licensing year. Permits specify units of entitlement or shares to an almost 277t ('whole weight') Snapper quota.

Key Features	WC Demersal Scalefish Fishery	Overlapping and Adjoining WC Demersal Fisheries		
		WC Demersal Gillnet & Demersal Longline Fishery	**SC Demersal Gillnet & Demersal Longline Fishery (Zone 1)**	**Gascoyne Demersal Scalefish Fishery**
	Kalbarri Area-35 Mid-West Area-55 SW Area-11 All permits have access to the limited commercial fishing hours in the Offshore area.			A minimum Snapper entitlement of 100 units is required to fish in this fishery.
	Inshore area permits/ entitlements are transferable.	Both licenses/entitlements are transferable	Both licenses/entitlements are transferable	Both permit/ Snapper entitlements/quota are transferable. The 30days/100 units of Snapper entitlement 'effort cap' for other demersal species fishing of is a non-transferable license condition
	Recreational (+Charter) Fishing Apart from recreational fisher requiring a recreational fishing boat license being a typically boat based activity, no other entry controls apply to recreational fishing in the West coast Bioregion	**Recreational (+Charter) Fishing** As for recreational fishing activity, entry control position is the same as the Demersal Scalefish fishing in the West Coast Bioregion.	**Recreational (+Charter) Fishing** As for recreational fishing activity, entry control position is the same as the Demersal Scalefish fishing in the West Coast Bioregion.	**Recreational (+Charter) Fishing** No entry controls apply on recreational fishing except for the limited number of charter boat licences.

Key Features	WC Demersal Scalefish Fishery	Overlapping and Adjoining WC Demersal Fisheries		
		WC Demersal Gillnet & Demersal Longline Fishery	**SC Demersal Gillnet & Demersal Longline Fishery (Zone 1)**	**Gascoyne Demersal Scalefish Fishery**
	except for limited entry licensed fishing (charter) tour operators.			
8.2 Catch Controls	No explicit catch quota limits on commercial, or, effectively, recreational use. While mixed specie daily bag/boat catch limits apply to recreational fishing, there is in effect, no entry control or controls on fishing tour patronage numbers.	No explicit catch quota limits on commercial. While mixed specie daily bag/boat catch limits apply to recreational fishing, there is, in effect, no entry control or controls on fishing tour patronage numbers.	No explicit catch quota limits on commercial While mixed specie daily bag/boat catch limits apply to recreational fishing, there is, in effect, no entry control or controls on fishing tour patronage numbers.	Snapper ITQ operate and a minimum unit holding is required to fish, there is no explicit catch quota limit on other commercially caught demersal species in the fishery. Apart from a limited number of Snapper tags to an inner area of Shark Bay, there is no catch quota limits on recreational take.
9. Input Controls				
9.1 Area	Fishery divided into 5, defined areas; 4 inner shore (SW, Metro, Mid-West and Kalbarri) in waters out to 250m deep and 1 ('offshore') in the extensive, deeper, waters where little line fishing catch history or experience exists to date. The defined areas are not species specific but designed to be	Fishery operates as one area.	Fishery has 3 zones with zone 1 overlapping the southern end of the WCDSF.	Fishery operates as one zone

Key Features	WC Demersal Scalefish Fishery	Overlapping and Adjoining WC Demersal Fisheries		
		WC Demersal Gillnet & Demersal Longline Fishery	**SC Demersal Gillnet & Demersal Longline Fishery (Zone 1)**	**Gascoyne Demersal Scalefish Fishery**
	indicative of the gradation in fish species that occurs moving from the temperate waters in the south to the warmer northern waters of this fishery. Closures The Metro 'Inshore' area closed to commercial fishing and the exclusive domain of recreational fishing. WC Bioregion closed to recreational demersal scalefish fishing from 15 Oct to 15 Dec. Defined waters around the Abrohlos Islands also closed to both commercial and recreational fishing.	Closures The areas of waters that correspond to the WCDSF defined Metro 'Inshore' area are closed to commercial fishing and the exclusive domain of recreational fishing.		Closures Commercial fishing vessels not permitted to operate in inner Shark Bay nor fish between 21°56's and 23°07's.

Key Features	WC Demersal Scalefish Fishery	Overlapping and Adjoining WC Demersal Fisheries		
		WC Demersal Gillnet & Demersal Longline Fishery	**SC Demersal Gillnet & Demersal Longline Fishery (Zone 1)**	**Gascoyne Demersal Scalefish Fishery**
		WC Bioregion closed to recreational demersal scalefish fishing from 15 Oct to 15 Dec Defined waters adjacent to the Abrolhos Islands also closed waters to commercial and recreational fishing.	WC Bioregion component of Zone closed to recreational demersal scalefish fishing from 15 Oct to 15 Dec?	

Key Features	WC Demersal Scalefish Fishery	Overlapping and Adjoining WC Demersal Fisheries		
		WC Demersal Gillnet & Demersal Longline Fishery	**SC Demersal Gillnet & Demersal Longline Fishery (Zone 1)**	**Gascoyne Demersal Scalefish Fishery**
9.2 Fishing Time	Annual 'capacity' of each fishery area specified in terms of limited allowable fishing hours.[3] Annual allowable fishing hours in each of the 3 inshore areas pro-rata allocated to permit holders based on entitlement units held in that area. Allocated annual allowable inshore area fishing hours transferable among permit holders. Offshore area annual allowable fishing hours not allocated and available to permit holders on 'first in, first use' basis. Utilization of allocated catching hours is monitored and the meter starts on entry to the area. A minimum, 'flag fall', hours/fishing trip apply on entry. These minima vary between areas. SW Area time entitlement can be consumed at variable rates depending on the number of lines used [4]	Fishing time is monitored The amount of gear used determines the rate at which time entitlement is consumed	Fishing time is monitored The amount of gear used determines the rate at which time entitlement is consumed	Fishing time monitored

Key Features	WC Demersal Scalefish Fishery	Overlapping and Adjoining WC Demersal Fisheries		
		WC Demersal Gillnet & Demersal Longline Fishery	**SC Demersal Gillnet & Demersal Longline Fishery (Zone 1)**	**Gascoyne Demersal Scalefish Fishery**
9.3 Boats	Commercial fishing permits must be attached to a licensed, 'authorised' fishing boat. Licensed fishing boats must be fitted with an approved and tested 'ALC'[5] monitoring device to be authorized A permit with entitlement units to multiple inshore areas may be attached to an authorized boat Multiple 'within' fishery permits both within and across 'inshore' areas may be attached to an authorize boat. Multiple 'across' WC demersal fisheries permits may be attached to an authorized boat.	Commercial fishing permits must be attached to a licensed, 'authorised' boat fishing boat. Licensed fishing boats must be fitted with an approved and tested 'ALC'[5] monitoring device to be authorized Multiple 'within' fishery permits may be attached to an authorized boat	Commercial fishing permits must be attached to a licensed, 'authorised' boat fishing boat. Licensed fishing boats must be fitted with an approved and tested 'ALC'[5] monitoring device to be authorized Multiple 'within' fishery permits may be attached to an authorized boat	Commercial GDSF MFL must be attached to a licensed, 'authorised' boat fishing boat. Currently 18 boats actively fish the fishery Licensed fishing boats must be fitted with an approved and tested 'ALC'[5] monitoring device to be authorized Multiple 'within' fishery MFLs may be attached to an authorized boat

Key Features	WC Demersal Scalefish Fishery	Overlapping and Adjoining WC Demersal Fisheries		
		WC Demersal Gillnet & Demersal Longline Fishery	**SC Demersal Gillnet & Demersal Longline Fishery (Zone 1)**	**Gascoyne Demersal Scalefish Fishery**
		Multiple 'across' WC fishery permits may not be attached to an authorized boat	Multiple 'across' WC fishery permits may not be attached to an authorized boat	Commercial GDSF MFL and WCDSF permit may be attached to an authorized boat.
9.4 Fishing Method	Method limited to line [6] fishing. with allocated annual fishing hours based on up to 10 lines, except the SW where up to 20 lines can be used. If more than 10 lines on board or used during a fishing trip, annual allocated catching hours used is increased above the actual hours fished according to specified formula.	Method limited to demersal gillnet or demersal longline	Method limited to demersal gillnet or demersal longline	Fishing method limited to lines and not more than 10 lines per authorized boat at any one time.

Key Features	WC Demersal Scalefish Fishery	Overlapping and Adjoining WC Demersal Fisheries		
		WC Demersal Gillnet & Demersal Longline Fishery	**SC Demersal Gillnet & Demersal Longline Fishery (Zone 1)**	**Gascoyne Demersal Scalefish Fishery**
9.5 Gear	Max of 10 lines to be used for fishing from a boat at any time with each line limited to 30 hooks or gangs of hooks/line, except fishing in defined waters adjacent to the Abrolhos Islands where a dropline is limit is 3 hooks	Detailed specifications around gillnets (i.e. mesh size/depth and floats) and longline Gear must be removed from the water at least once each day. Gillnet and longline fishing cannot occur simultaneously.	Detailed specifications around gillnets (i.e. mesh size/depth and floats) and longline. Max. gear allowed is 8235m of gillnet or 2745 hooks Gear must be removed from the water at least once each day. Gillnet and longline fishing cannot occur simultaneously.	Max of 10 lines to be used per boat.
9.6 Departure Landing Ports	Specific designated ports	Specific designated ports	Specific designated ports	Specific designated ports

Key Features	WC Demersal Scalefish Fishery	Overlapping and Adjoining WC Demersal Fisheries		
		WC Demersal Gillnet & Demersal Longline Fishery	**SC Demersal Gillnet & Demersal Longline Fishery (Zone 1)**	**Gascoyne Demersal Scalefish Fishery**
9.7 Fishing Trips	Master of an 'authorised' boat with a permit or permits to fish within the fishery must lodge a pre-fishing trip nomination. Pre-trip nominations must be lodged showing which permit, what area(s) to be fished, and the 'port-to-port' details. Multiple area, nominated, trips for a single permit is possible. Trip variations subsequent to departure require the master to return to the nominated return port, unload catch and lodge a fresh pre-trip nomination after 2 hours. These trip nomination requirements apply where other attached permits are to be used.	Master of authorized boat must lodge a pre-trip nomination showing gear (net dimensions or longline hook numbers) being used and departure and landing ports.	Master of authorized boat must lodge a pre-trip nomination showing gear (net dimensions or longline hook numbers) being used and departure and landing ports.	Master of a boat must lodge pre-trip nomination and pre-departure notification before leaving port.
10. Gross Value of Demersal Scalefish Catch (2011-2012)	$ 5m	Approx. $0.4 m	Aprox.$0.5m	$ 3-4m

Note: [1] A suite of 3species initially (duhfish, Snapper, Baldchin Groper) but 2 further species added (Redthroat emperor and Bright redfish) for the 'inshore' areas where commercial fishing is permitted and also other species (Hapuka, Blue Eye trevalla, Bass cod) for the 'offshore' area. [2] Top 15 demersal species/species group caught by recreational/charter sector.[3] Annual allowable fishing times is 10488 hours for the Kalbarri area, 24398 hours for the Mid-West area, 6622 hours for the SW area and 2400 hours for the 'offshore area. [4]. Minimum entry flag falls are 20 hours for the Kalbarri are, 12 hours for the Mid-West, 8 hours in the SW and 12 hours in the 'offshore area. [5] 'ALC' mean automatic location communicators.[6] 'Line' means handline, dropline or troll lines. [7] 'Unit value' is the use of 288 hours of either 27 metres of demersal gillnet or 9 hooks on a demersal longline. There is a maximum of 13,340 units in the fishery. [8] Catch share guidelines based around 2005/06 resource use. A subsequent independent assessment in 2012 reviewed these proportional catch share guidelines based on revised 2005/06 catch data which amended the Dhufish 'guideline' shares to 38% (Commercial) and 62% (recreational, including charter) and Snapper to 79% and 21% respectively

Sources

West Coast Demersal Scalefish (Interim) Management Plan Amendment (No.3) 2013 (18 October 2013)
West Coast Demersal Gillnet and Demersal Longline Interim Managed Fishery Management Plan Amendment 2013 (27 September 2013)
Southern Demersal Gillnet and Demersal Longline Managed Fishery Amendment 2013 (31 May 2013)
Department of Fisheries Status Reports of the Fisheries and aquatic Resources of Western Australia 2012/13
Key Findings of the 2013 West Coast Demersal Scalefish Stock Assessment, FMP No. 262, November 2013

West Coast Demersal Scalefish Resource Stock Outcomes by 2012

These mixed species resource stocks have been in recovery since management changes were implemented in 2008 with the creation of a limited number of entry permits for commercial fishing and the subsequent creation of units of entitlements to substantially reduced allowable fishing effort (time) from 2009. Also at that time, reduced bag, boat, and possession limits and closures were applied to the recreational sector.

The adjoining GDSF was similarly placed under formal management arrangements from 2010 that incorporated the then pre-existing Shark Bay Snapper Quota system.

The management outcomes by 2012 reportedly show that, whilst the stock status and fishing levels in the GSDF are now considered to be ‘acceptable’, the outcomes for the West Coast Demersal Scalefish fishery have apparently allowed some level of recovery in demersal stocks but they have not yet recovered. Reportedly, adequate West Australian Dhufish stock recovery was apparent in all management areas at current reduced catch levels. Apparently, this was not evident for the two other ‘indicators’ species (Snapper and Baldchin Groper) where catches and fishing mortality were not reduced sufficiently to allow recovery of stocks of these species, particularly in the northern management areas where the bulk of these overfished species are caught.

These outcomes are reflected by the actual 2012 catch outcomes compared to the ‘reduced catch reference level shown in Table 26 below.

Table 26: West Coast Demersal Scalefish Resource-Reduced Catch Reference Levels and 2012 Catches (Tonnes)

Sector/Species	50% of 2005/06 Catch Level		2011/12 (or 2012) Actual Catches	
	WCDSF	WCDF	WCDSF	WCDF
Commercial Fishing				
All Scalefish	449-469		389	
Demersal Species	408	450	361	407
Dhufish	72	82	64	73
Snapper	120	126	170	180
Baldchin Groper	17	19	16	18
Recreational Fishing				
Demersal Species	250		200	
Dhufish	126		87	
Snapper	37		43	
Baldchin Groper	33		38	

Source: FMP No. 262, November 2013 and State of the Fisheries Report 2012/13

Whilst the 2012 total demersal scalefish catches were well within their respective ‘reduced catch reference levels, the catch levels by both the commercial and recreational sectors for Snapper and Baldchin groper by the recreational sector, although down significantly from the 2005/06 levels, were notably higher than their respective ‘reduced catch reference levels’.

These catch outcomes in the WCDSF occurred even though the unit entitlement (time) consumed was notably lower than the allowable levels for all management areas, as shown in Table 27.

Table 27: WCDSF Entitlement Units Consumed by Management Area-2009 to 2012

Area	Annual Entitlement (hours)	Entitlement Consumed (%)			
		2009	2010	2011	2012
Kalbarri	10,488	68	74	73	77
Mid-West	24,398	53	54	69	64
Metropolitan	0	0	0	0	0
South-West	6,622	48	45	40	51
Offshore	2,400	34	84	37	86
Total	43,908	55	59	64	67

Source: FMP No.249, July 2013

There is an apparent under-estimate of entitlement consumption, particularly with regard to the SW management area where almost 24% of the annual entitlement units (time) were left unallocated on issued permits[52]. Leaving this aside, under consumption of entitlement is usually associated with constraints that limit the freedom of commercial fishers to use their conferred entitlement units (what are referred to as institutional impediments.[53]) It can also be associated with operational inefficiencies (including the risk management approaches adopted by individual fishers to utilization of annual fishing time entitlement during the course of the licensing year) in the harvest sector. The data available were insufficient to identify the extent and relative significance of institutional impediments and/or operational inefficiencies within the harvest sector on the optimization of net returns to the sector.

The catch share outcomes in 2012 compared to the proportional catch share guidelines that were operative over this period showed mixed results. These outcomes are presented in Table 12 below.

Table 28: Commercial and Recreational (including Charter) Catches and Catch Share Allocations-2011/12 (or 2012)

Species	Commercial Catch	Recreational Catch	Shares (%)		Catch Share Allocation & Proportional Guidelines
	tonnes	tonnes	Commercial	Recreational	
All Demersal	407	200	67	33	64% com 36% Rec
Dhufish	73	87	46	54	40% com 60% rec
Snapper	180	43	81	19	80% com 20% rec
Baldchin Groper	17	38	31	69	35% com 65% rec

Source: FMP No. 262, November 2013

52 The West Coast Demersal Scalefish (Interim) Management Plan Amendment (N0.3) 2013 Schedule 5 set the capacity of SW area as shown in Table 4 above, whilst Schedule 6 shows the units conferred in that area total 5071 hours.

53 For example, there were several individual unit entitlement (time) holdings on issued permit that were either less than the' entry flag' fall required to fish in the particular management area or less than that required to undertake a typical 2 day fishing trip in this fishery. With the transaction cost associated with temporary transfer on unused annual fishing time entitlement (i.e. time and other costs, including a S20 transfer duty on each transaction, to complete, lodge and obtain approvals) the few transactions that have occurred tends to point to the possibly that unused entitlements become of little or no value.

Management Challenges and Economic Governance-Where to from Here

As already noted, the circumstances along the supply chain for the finfish catch offers little significant opportunity to increase returns to fishers. However, in the current situation, where, despite the effort reductions since 2008, recently re-assessed stock levels for the West Coast Demersal Scalefish fishery pointed to continued overfishing, there will be limited opportunities to increase catch under current or any proposed management arrangements at least in the immediate future.

The current approach to management based on effort reduction indirectly targets the required 'reference level' catch outcomes consistent with stock recovery. This approach will take some time (possibly up to 10 years) to achieve the stock sustainability objective.

If the fish stock recovery is not occurring at a faster enough rate and/or the catch shares between the user groups require some further 'tweaking' given the existing disparity between current shares and the Government -adopted target shares, then a new round of challenges arise for fisheries management.

Allocation of the Fish Resource between User Groups

Under the current interim management arrangements, the fishery is managed to achieve target catch shares. The target is reflected in 'proportional catch share guidelines' implemented through the Integrated Fishers Management policy. The commercial fishery is limited entry based on licences with effort managed through a mix of controls on time and activities. Recreational participation is not directly restricted but recreational fishers need to have a recreational fishing licence, a boat licence and are subject to species bag limits.

The Government recently adopted revised proportional guidelines between commercial and recreational sectors for West Australian Dhufish and Snapper following an Advisory Committee Report[54]. The revised proportional guidelines re-aligned the pre-existing guidelines (as shown in Table 5 above) for Snapper and West Australian Dhufish by increasing slightly the recreational share and marginally reducing the commercial sector share. The change reflected revisions to 2005/06 catch data and in effect preserved the baseline proportional catch shares in existence and intended at that time.

The objective of the catch share guideline is to optimize the value of the fishery to society. However, optimization of the value of the fishery for any 'desired' overall catch reductions, would in theory mean a reduction that is less for the sector where the loss of marginal net benefit value is greatest and more for that sector where the loss of marginal net benefit value is smallest[55]. The desired catch reductions between the sectors if this objective is to be pursued may not turn out to be proportionally the same for Snapper, Baldchin Groper and West Australian Dhufish once the appropriate analysis has been done.[56]

In these circumstances, designing management arrangements and the choice of management tools to remain consistent with the mandated objective of optimizing the economic benefits from the use of the resource will be an ongoing challenge.

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[54] Integrated Fisheries Allocation Advisory Committee to the Minister for Fisheries, West Coast Demersal Scalefish Allocation Report, FMP No. 249, July 2013

[55] Marginal net economic benefit values have a specific meaning and are not the gross value of commercial or recreational activities. The definition and measurement of these values in the West Coast 'Wetline' Fishery are detailed in a separate study by McLeod and Nicholls (op cit 14)

[56] See McLeod and Nicholls, Optimizing the Economic Benefits from Commercial and Recreational Use of the Resource and Lindner, McLeod and Nicholls, Dynamic Modelling of Optimal Resource Use. Both reports include the 'Wetline Fishery' case study.

Taking Stock of Outcomes from the Current Interim Management Arrangements for the West Coast Demersal Scalefish Fishery

If the current interim management arrangements are to be 'tweaked' in view of latest stock assessment outcomes[57] and/or consideration is to be given to the design of future management arrangements to replace the existing interim arrangements to take this fishery to next phase of management plan status, this poses a new set of challenges for fisheries management.

In that event, the outcomes over 4 years of the current interim arrangements give an insight into the likely effectiveness and consequence of continuing to rely on the existing indirect (effort) control tools to achieve the 'reference' catch level reductions for both sectors and the desired recovery rate for fish stocks.

In response to the implementation of indirect fishing controls commercial fishers typically change their fishing behaviour in ways that improve catching efficiency (within the introduced controls) to achieve the best possible net return outcome. This is typically driven by changes to when they go fishing, where they fish, the number and duration of fishing trips, the catchability of specie(s), and, in this multi-species fishery, the specie(s) targeted.

The experience in the WCDS fishery since the implementation of effort limits (fishing time) in this fishery in 2009 appears to have been no exception. The raw catch per unit of effort (kilograms of fish caught for each hour spent on fishing trips) derived from catch data supplied by the Fisheries Department, suggests efficiency improvements of almost 6% for the fishery generally over the period since the introduction of indirect controls (2009) to latest year (2012) for which data were available (see Figure 49 below)[58]. Such efficiency improvements appear to have been particularly significant in the Mid-West inshore area with continuous improvements amounting to 37% over the period, whilst in the Kalbarri area a notable improvement initially but slipped away in 2012 to record a modest 5% improvement over the 2009 level. The South West inshore area exhibited a notable initial improvement that also slipped in 2011 and again in 2012 to be noticeably less than the 2009 level.

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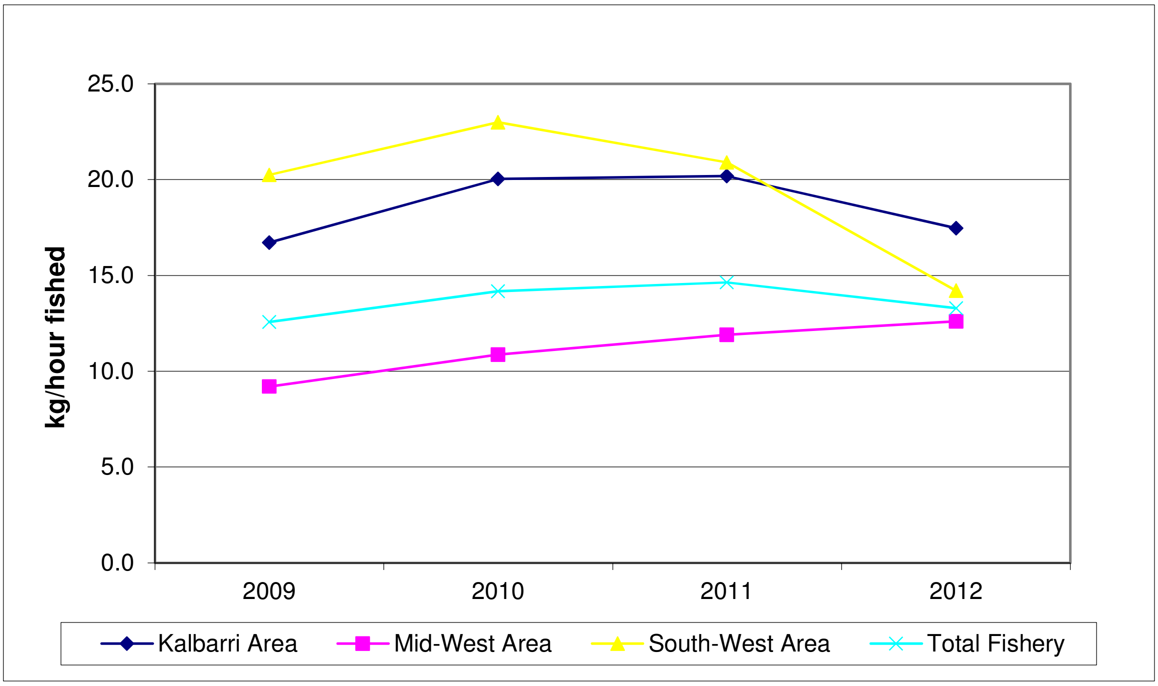
[57] Key Findings of the 2013 West Coast Demersal Scalefish Stock Assessment, FMP No. 262, November 2013 reported that 'reference' catch levels had not been met for Snapper and Baldchin Groper with a slower than desired mortality rate recoveries.

[58] These results need to be interpreted with caution. The data have not been standardized to allow for various other variables that can impact of catch per unit of effort such as the number of hooks used, vessel type, the different skill of individual boat skipper, and the like. A standardized data set is published by the Fisheries Department's in its most recent 'Status of demersal finfish stocks on the West Coast of Australia' (Fisheries Research Report No.253, 2014, page 50). The graphs data sets related to only certain of the 'key' indicators species in each of the areas of the fishery and does not include the most recent catch data.

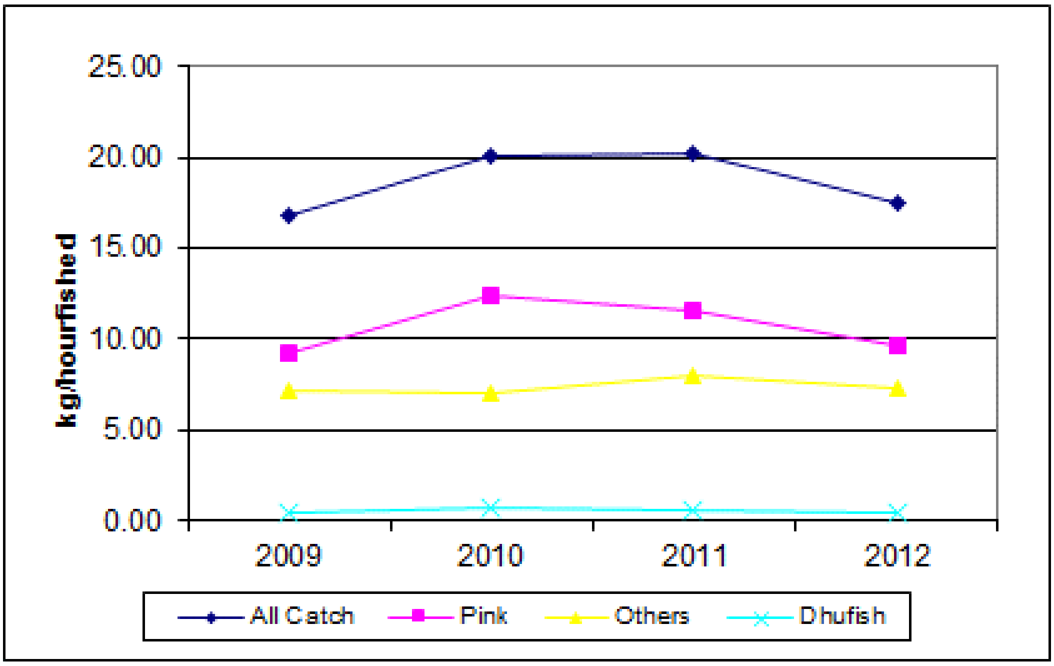
Figure 49: Catch per Unit of Effort West Coast Demersal Scalefish Fishery



Source: Data Supplied by Department of Fisheries

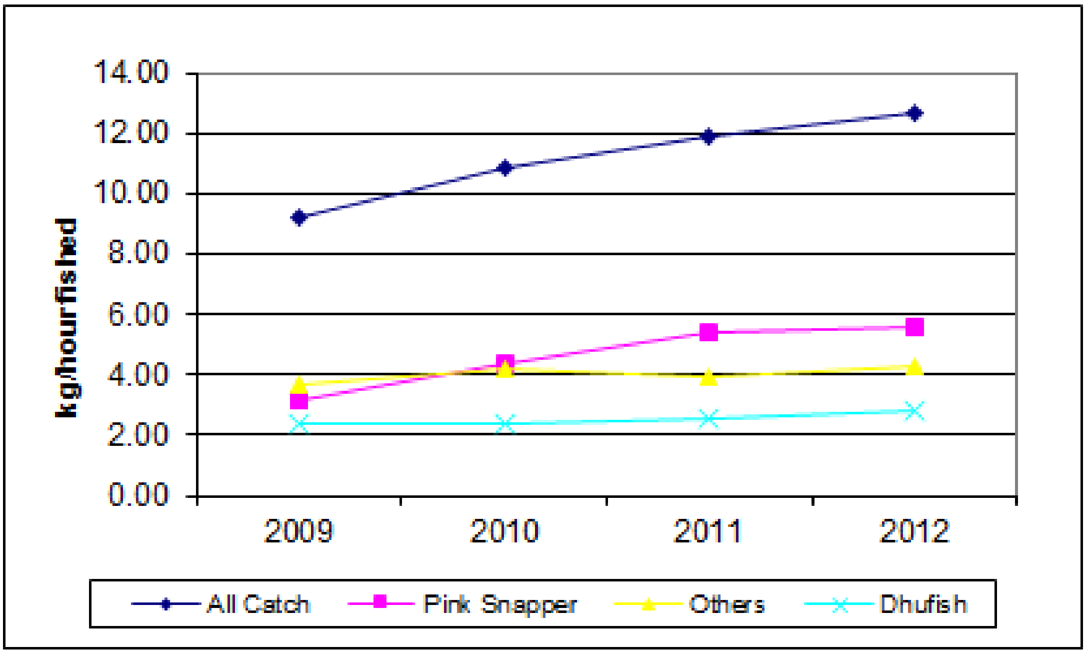
This aggregate fishery level response is the summation of outcomes that occurred in each of the underlying inshore management areas since the implementation of fishing time limited units of entitlement in the fishery in 2009. These are shown in the graphs below. , there was a targeting of demersal species other than Snapper and West Australian Dhufish where catch per unit of effort declined markedly with notable improvements in the catch per unit of effort of Snapper (almost 10%) and West Australian Dhufish (46% but from a low base) by 2012. In the Mid-West, there is marked targeting of Snapper and to a much lesser degree West Australian Dhufish, whilst, in the Kalbarri area, there was initially marked targeting of Snapper but subsequently interposed with a focus on catching other species (other snapper, emperor) when net returns per hour fished for the trip were presumably better.

Figure 50: Kalbarri Area Catch per Unit of Effort



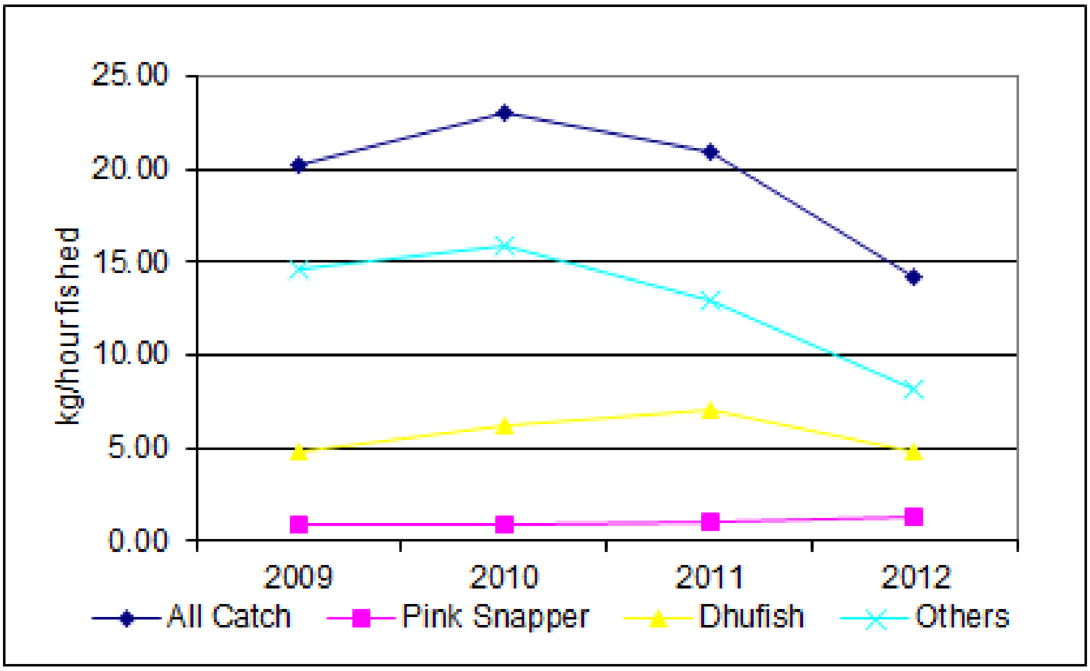
Source: Data Supplied by Department of Fisheries

Figure 51: Mid-West Catch Per Unit of Effort



Source: Data Supplied by Department of Fisheries

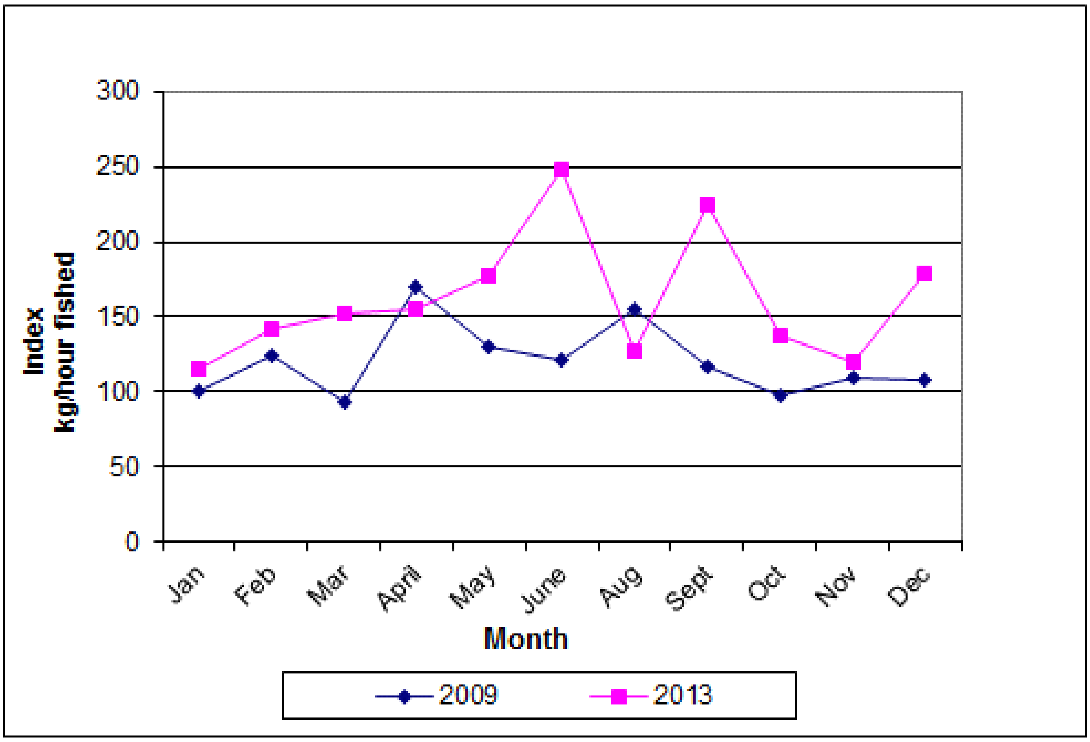
Figure 52: South West Area Catch Per Unit of Effort



Source: Data Supplied by Department of Fisheries

These individual management area outcomes are a summation of those of individual fishers' who fished in the respective areas over this period. Individual fisher data from a limited number of operatives in the northern areas of the fishery who fished at both the time of implementation of unit of entitlement (fishing time limits) system in 2009 and in most recent licensing year (2013) exhibited a quantum lift in the kilograms of fish caught for each hour fished (see Figure 53).

Figure 53: Index of Monthly Catch per Unit of Effort: Jan 2009=100



Source: Data Supplied by individual northern inshore area fishers

These high level data sets are consequences of individual commercial fisher's operational fishing decisions. The decisions about when to fish, where and how long to fish and what species to target that underlie commercial fishing effort are driven by the desire to achieve the best net returns (prospective price less variable trip costs) for the number of hours fished (effort) for each trip. This is depends on 'catchability' of species in this multi-species demersal scalefish fishery and the relative net return prospects for respective species.

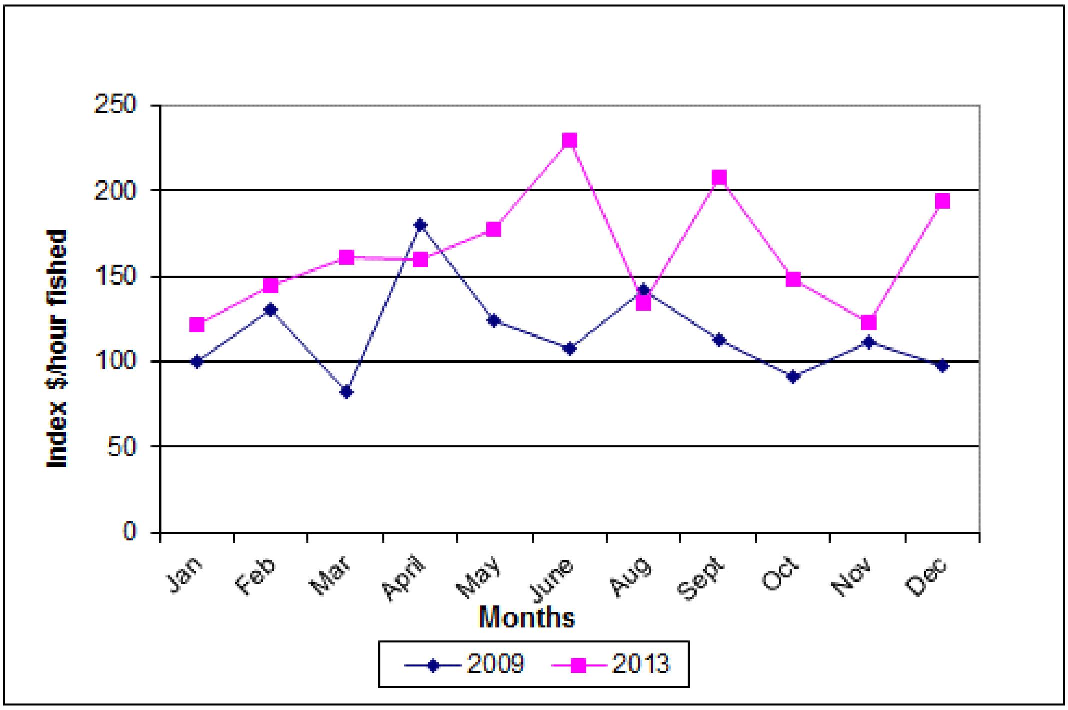
The variable costs are those directly related to each trip and exclude those costs which are incurred to run the fishing operation regardless of trip numbers and catch volumes (i.e. the fixed costs like those typically associated with boats, gear, licenses, boat surveys, repairs and maintenance, depreciation). The variable costs for each trip typically reflect fuel and bait, and, for any given trip time, they are generally the same regardless of which species is targeted.

In these circumstances, and, given crew remuneration is generally based on a percentage share of the revenue earned; the species targeted on any trip will be the one that offers prospects of the best revenue outcome (expected catch volume for the trip time by the prospective net prices at the time). The best returning prospects could be targeting different species at different times during the course of a licensing year as relative expected 'catchability' of the species and net prices vary over the year.

The individual fisher trip catch and price data available from operations in the northern inshore management areas showed catch revenue for each hour fished for all trips in 2013 was more than 23% higher than it was in 2009. This outcome appears to have had less to do with the price where the annual average return for each kilogram of fish caught increased by less than 4% with no apparent material difference in the species caught between 2009 and 2013.

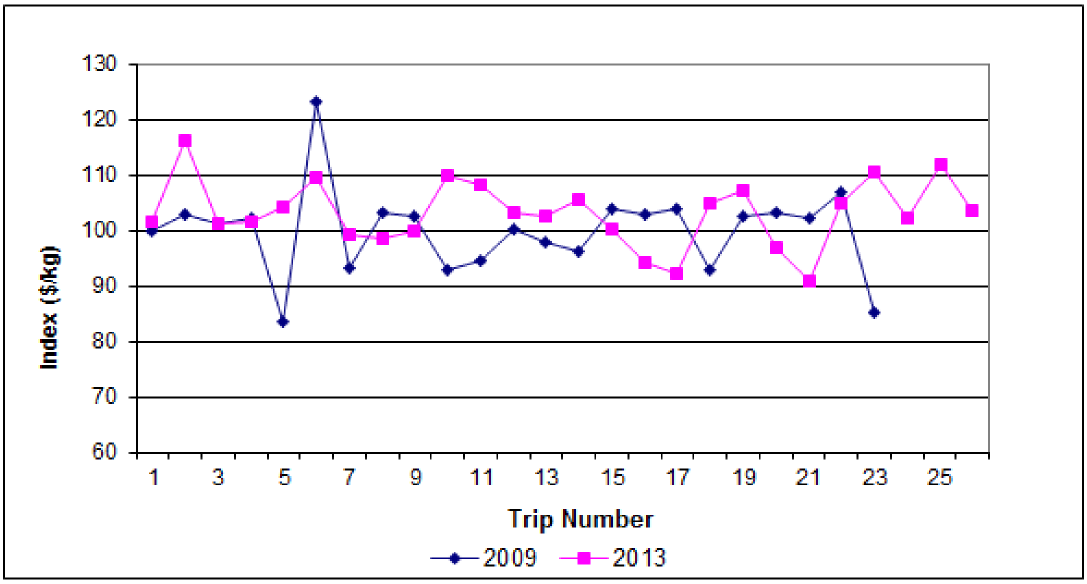
The improved monthly catch revenue per hour fished (Figure 54), appears to be driven by increased catch per unit of effort, changes to the pattern of trip catch price and the species targeted (see Figure 55). There is 7% less time overall spent fishing (reflecting 15% more trips, but, on average, 17% less time spent on each fishing trip) between the years.

Figure 54: Index of monthly catch revenue per unit of effort. Jan 2009=100



Source: Data supplied by individual northern inshore area fishers

Figure 55: Index of Average Trip Catch Prices: Jan 2009=100.



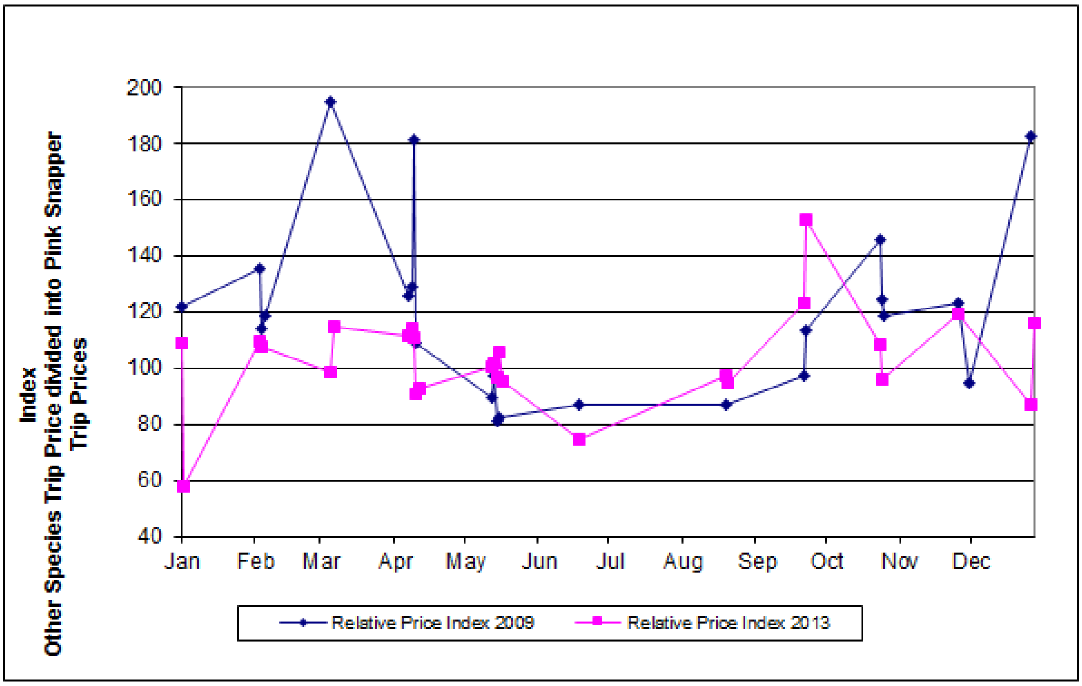
Source: Data supplied by individual northern inshorearea fishers

The relative catch price pattern between the species (see Figure 56) shows Snapper trip prices (observations above the index of 100) are higher than the 'other' species trip price, whilst those below the reverse is the case. The indices presented need to be interpreted with some caution given the 'other species' represents a weighted average price for the range of non-Snapper demersal scalefish species caught. Notwithstanding this qualification, it does not materially detract from the validity of the following observations that can be drawn from these indices.

The relative price patterns for both years highlight the attractiveness of targeting Snapper when the catchability of Snapper is expected to sufficiently better than for other species. This situation appears to have been the case for better part of the licensing years.

Whilst certain species like West Australian Dhufish or Baldchin Groper for instance may attract higher 'beach' prices on average than Snapper, the 'catchability' of these species is generally much lower than Snapper and consequently the trip catch revenue return per time fished would be less.

Figure 56: Index of Relative Catch Prices by Species



Source: Data supplied by individual northern inshorearea fishers

If there is a desire of fisheries management to rein in commercial Snapper catches levels in each of the inshore northern management areas by reducing the value of existing entitlement units on the basis that the existing levels continue to remain indicative of overfishing in these areas, then unintended outcomes could be expected.

This poses a dilemma for fisheries managers. If the observed individual commercial fishers' response to the implementation of the unit entitlement system is indicative of fishers' behaviour generally in both northern areas then, given that the exhibited relative price pattern could be expected to persist, reductions in fishing time entitlements could see commercial fishers targeting Snapper with increased intensity. This means snapper catch levels might not fall to the desired 'reference' levels, or not fall as quickly. Consequently, the recovery in the stock mortality rate for this 'key' indicator species may remain lower than desired by fisheries management.

Possible Management Approaches to Achieving Reduced Catch Allowances

Based on available data the following can be taken as given:

- current management arrangements are not reducing harvest and recovering stocks as quickly as fisheries managers would like to restore sustainability of fish stocks, nor are they achieving the Government's catch share targets;
- recreational effort has the potential to increase through a combination of population growth, rising real incomes and 'baby boomers' retiring;
- commercial fishers have and will continue to respond based on optimizing their returns and this is unlikely to align perfectly with harvest objectives of fisheries managers for the key benchmark species under current management arrangements;
- a period of reduced commercial fishers' effort entitlement (allowable fishing time) will, ceteris paribus, negatively impact catch levels and fisher returns, and
- the scope to enhance commercial fishers' returns by adjusting market arrangements down the supply chain (including using generic advertising and/or promoting independent sustainability accreditation) is, at best, limited.

This being the case, the best outcome appears to be the one that is based on a management policy design that allows for greater certainty in the achievement of fisheries management objectives and in a way that allows commercial fishers as much flexibility as is possible to achieve maximum possible efficiency in harvesting activities. The logical place to look to for opportunities to improve returns to commercial fishers is in the way fisheries management rules are designed.

As already noted, under the current interim management arrangements, the fishery is managed to achieve target catch shares. The commercial fishery is limited entry based on licences with effort managed through a mix of controls on time and activities. Recreational participation is not directly restricted but recreational fishers need to have a recreational fishing licence and are subject to species bag limits.[59]

The focus here is on the commercial harvest rules. The existing complex array of fishing management controls for demersal fish taken in the presently defined west coast bioregion have evolved over many years. Given this wild capture catch has now exceeded sustainable levels, the time may be appropriate to take stock of the outcomes from past measures and consider whether there may a simpler, more cost effective, way to structure the existing complex, overlapping, array of fisheries management controls.

There is an existing understanding of the 'baseline' costs to the Department of managing these fishing activities under the existing arrangements against which the likely costs of alternative management approaches and designs could be assessed. Such analysis should not be solely focused on the implications for Fisheries' management costs. The likely efficiency gains or losses for the commercial fishing sector of alternatives need to be carefully considered if the best approach to achieving the fish take and stock sustainability objectives

[59] Although commercial fishing is the focus here, it is worth noting that the reduced bag limits and two month demersal closure for recreational fishing have had a positive impact. Recreational catch is close to the 50% catch reduction targeted by the managers, with the exception of Baldchin Groper. A recent FRDC study shows that recreational fishers in the West Coast Demersal Fishery have responded to bag limit reduction and have not shifted effort spatially in response to the two month metropolitan area closures. (McLeod et al. 2009).

that allows the best possible opportunity for optimization of economic benefits to the community from the demersal fishery is to be chosen.

Whilst it is outside the scope of this research to be prescriptive about what might be the management approach and design that could best achieve the objectives, the following table presents a spectrum of possible options. In doing so, it looks at the likely possible implications of the alternatives presented.

The table has been prepared based on the 'givens outlined above and against the background of the Fisheries Department's latest stock status report[60]. This report highlighted commercial take of Snapper in the northern areas of the fishery and recreational sector take of Baldchin Groper remained at unsustainable levels jeopardizing the recovery in fish stocks despite commercial fishing effort reduction and tighter recreational bag and possession limits, including an introduced, State-wide, recreational fishing boat licenses (fees), over the past 5 years.

[60] Fisheries Management Paper No. 262. 'Key Findings of the 2013 West Coast Demersal Scalefish Resource Stock Assessment' (November 2013)

Table 29: Possible Alternative Management Approaches and Implications

Nature of Approach	General Design Thrust	Implications		
		Catch Objective Certainty	Fisheries Management Cost Impacts	Sector Impacts
Indirect Controls	Commercial Sector . Cut existing determined northern area ‘capacities’ (fishing time) (1)	Uncertain . Potentially reduces the overall demersal catch which is currently within ‘acceptable’ levels . Unlikely to reduce Snapper take to the ‘target’ levels as this species offers the best return/effort unit under existing relative returns for demersal species	Minimal . Minor increase in compliance costs might be possible	Negatively . Reduces demersal catch, and income from demersal fishing. . Reduces profitability of demersal fishing operations with limited opportunities to improve harvest efficiency whilst continued to be ‘straight jacketed’ by retention of existing raft of indirect (input) controls. . Potential risk of reduced catch shares below the Government-adopted targets, if recreational entry/catch levels remain uncontrolled
	Recreational Sector . Reduce ‘bag’/possession limit components for Baldchin Groper	Uncertain . Unlikely to reduce recreational take whilst entry/catch levels remain uncontrolled	Minimal . Minor increase in compliance costs might be possible	Potentially Positive . Potential benefit from unintended improvement in catch shares beyond the Government-adopted ‘targets’.

<table>
<tr><th rowspan="2">Nature of Approach</th><th rowspan="2">General Design Thrust</th><th colspan="3">Implications</th></tr>
<tr><th>Catch Objective Certainty</th><th>Fisheries Management Cost Impacts</th><th>Sector Impacts</th></tr>
<tr><td rowspan="2">Mix of Indirect and Direct Controls</td><td>Commercial Sector

. Adopt a variant of the GDSF type management model by introducing a transferable Snapper quota scheme within the existing determined ‘capacities’ (allowable fishing time) (2) for the overall west coast bio-region or the northern areas only.

. This approach could possibly operate within each of the two or as a single scheme covering both northern areas, perhaps in conjunction with GDSF.

. Widening the allowable fishing methods might be possible to include a pre-trip option to nominate the use of lines or long-lines.</td><td>Certainty around the Snapper take and greater confidence around the other demersal species and total catches.</td><td>Negative

Possibly increased initially to implement a quota monitoring system, although this may not prove to be overly costly with modification of similar existing computer systems</td><td>Possibly Negative or Positive

Certainly reduced total demersal catch and income. Improved scope for harvesting efficiency gains if certain input controls can be eased. (e.g. one not two northern areas where the trip variation rules could become redundant, and/ or permit the use of longline)

. Potential risk of reduced catch shares below the Government-adopted targets, if recreational entry/catch levels remain uncontrolled, except perhaps Baldchin Gropers if a limited number of recreational fishing tags are issued.</td></tr>
<tr><td>Recreational Sector

. Complement existing bag, possession limits with a limited number of issued Baldchin Groper tags.</td><td>Greater certainty around Baldchin Groper take but less confidence around other demersal take while entry/catch levels remain uncontrolled.</td><td>Negative

Increased with the need to administer a Baldchin Groper tag allocation mechanism and possibly increase compliance monitoring activity</td><td>Potentially positive

. Potential benefit from unintended improvement in catch shares beyond the Government-adopted ‘targets’, except for balchin groper with limited number of issued take tags.</td></tr>
</table>

Nature of Approach	General Design Thrust	Implications		
		Catch Objective Certainty	Fisheries Management Cost Impacts	Sector Impacts
Direct Controls	Commercial Sector . Adopt a total quota for the demersal catch (3) complemented by a sub-set Snapper (or other specie) specific quota(s), as appropriate for the west coast bio-region. . All quota(s) allocated to commercial fishers' in the form of ITQ. This could be based on fishers' existing unit entitlement holdings. . Provides scope to possibly rationalize demersal catch across the existing array of different method controlled demersal fisheries in the west coast bio-region. . Provides scope to remove or ease some or all of the existing complex array of indirect controls (area, time, fishing method, gear, trips) over harvest activities	Greater certainty of achieving fisheries managers 'desired' catch levels overall and for sub-set quota species. The appropriate quota mix offers greater confidence of achieving the 'preferred' demersal stock recovery rates and meeting the catch share targets if combined with entry/catch levels controls on recreational fishing..	Negative . Likely to involve increased management cost for the Department of Fisheries to introduce and manage a quota management model.	Potentially positive . Reduces Snapper catch and income rather than total catch and income of the indirect control approach. . Removal or easing of indirect controls offers commercial fishing operations increases flexibility to improve harvest efficiency. . Potential risk of unintended reduction in catch shares below the targets if entry/catch limit controls for recreational fishing in the west coast bio-regional are left uncontrolled.
	Recreational Sector	Positive	Negative	Potentially Negative

Nature of Approach	General Design Thrust	Implications		
		Catch Objective Certainty	Fisheries Management Cost Impacts	Sector Impacts
	. Introduce tighter entry/ catch level limits on recreational fishing	. Greater certainty of achieving fisheries managers 'desired' catch levels . Provides greater confidence of achieving the 'preferred' stock recovery rate and meeting the catch share targets if combined with commercial catch quota.	. Likely to involve increased management cost for the Department of Fisheries to introduce and manage entry/catch level controls	. With any restriction on, or, losses of, open access and reductions in catch levels will be seen by the recreational fishing sector to .be taking away a longstanding access right and viewed as a loss of utility.

Assumptions:

(1) Assumes any proposed 'cut' would represent a reduction in used fishing time entitlements.
(2) Existing 'Capacities' (allowable commercial fishing time) could perhaps be continued given total demersal and 'benchmark' species catch levels, except Snapper in each of the two northern area are reportedly appropriate.
(3) Given total demersal take is reportedly adequate, then the total catch quota(s) could presumably be set accordingly.

Discussion

Merits of a supply chain approach to analysis of governance issues in fishery management

The primary responsibility of the Department of Fisheries is to conserve, develop and manage the fish and aquatic resources of the State for the benefit of current and future generations. It does this through managing and licensing fishing activities, and by protecting the environment and ecosystems on which fish depend. Such measures create relationships between government and market agents (producers, processors, marketers, customers) that can be viewed as a governance structure. The details of this governance structure are an important determinant of overall economic performance, not only of the catching sector, but potentially also of the entire supply chain.

In most fishery supply chains the principal components are the catching sector and the processing sector. The external governance structure established by fishery management can enhance value through the supply chain by influencing behaviour of agents in both sectors, and the relationships between them embedded in private contractual arrangements. For instance, in order to develop long term marketing strategies and make efficient investments in processing capacity, the processing sector requires a reliable and consistent supply of fish. In turn, this will enable the catching sector to optimize its operations and investments. From the perspective of fishers, enhanced value occurs when the impact of governance secures improved long term economic returns. The potential areas of involvement by government (external governance) that might enhance value are primarily in harvest strategies and marketing.

Harvest strategies ensure that harvests are biologically sustainable. Where recreational fishers are able to access the resource, external governance needs to include a specific resource sharing strategy. However, insofar as the economic performance of the supply chain is concerned, governance also needs to encourage fishers to harvest the designated catch with maximum efficiency. To this end, the specific harvest rules and mechanisms chosen (e.g. quotas versus input controls) have a potentially significant impact on economic outcomes.

In recent years, the Government has been "implementing a number of reforms aimed at transforming fisheries management in Western Australia and meeting future challenges. The reforms are focussed on removing unnecessary regulation and simplifying fisheries laws, establishing a more structured and risk-based approach to management of fish stocks, developing clearer management objectives and harvest strategies for fisheries, and working on innovative approaches such as co-management." [Department of Fisheries, 2012 Western Australian Government Fisheries Policy Statement, March 2012, p.3.].

Underpinning these reforms is recognition that sustainable, profitable, healthy and viable fisheries are of the utmost importance to Western Australia's diverse and growing population. Hence, the primary aim of fishery management strategies is to ensure the long term sustainability of Western Australia's fish and aquatic resources, and subject to this overarching requirement, to also optimise the socio-economic benefits from these resources.

Involvement by government in marketing needs to be interpreted broadly. Government can, and often does play a role in ensuring the integrity of the supply chain as part of marketing. In the case of fisheries, accuracy in labelling by species and country/locality of origin are examples. Similarly, to the extent that sustainability and related quality certification is an important aspect of marketing, government sometimes plays a role. On the other hand, generic advertising of fish by government to increase demand and benefit fishers is much less common.

Findings from a supply chain analysis for Western Rocklobster

The supply chain for WRL consists almost entirely of a catching sector and a processing and marketing sector. In the past decade, catch volume has more than halved, and almost all is exported to Greater China (GC) as live product. Also in the past few years, the nominal price has increased by more than 50%, and is now at historical highs. A key question for future governance of the fishery is the impact on price and returns if the current low allowable catch levels are built into future harvest rules even after stock abundance recovers in an attempt to sustain high prices.

Analysis of the evidence shows that the lobster market is a competitive world market in which many related types of lobster are all seen as quite close substitutes for WRL, albeit with price differentials to reflect size and quality differences. Consequently, all lobster prices tend to move more or less in parallel. Moreover, because the supply of WRL to GC accounts for a very small part of supply of all lobster to this market, the long run demand for WRL exports is extremely elastic. Therefore, ceteris paribus, restricting sales will result in little if any long run increase in prices. Testing for cointegration across time series of lobster prices confirmed these findings.

In recent years, Government has implemented some transformative reforms to the external governance structure of the Western Rocklobster fishery (WCRLF), including in particular a transition from an effort controlled management system to a new regime based on individual transferable quotas (ITQs). As part of this process, a Harvest Strategy is being developed that at its core, will comprise a set of decision control rules for annually setting the Total Allowable Commercial Catch (TACC). Some of these governance rules seem designed to entrench the decline in catches from historic highs of nearly 14,000 tonnes to recent catch levels of 5,000 to 6,000 tonnes. Like any significant changes to industry governance structure, there is considerable uncertainty about how such changes will impact on the operations and profitability of the various sectors in the supply chain.

Two key objectives will underpin the Harvest Strategy and Control Rules (HSCR) framework. A sustainability objective that sets a floor "threshold value" to egg production capacity is the primary overriding objective of the HSCR, with the aim of maintaining stock biomass at levels last experienced in the mid-1980s.

A second and subordinate TACC setting objective is to increase lobster abundance so as to reduce catching costs, and increase economic returns. It is envisaged that this will be achieved by fixing the TACC at a conservative level so as to limit the Legal Proportion Harvested (LPH) to some maximum proportion, and thereby build catch rates to a target level.

To enable investigation of some of the consequences of the proposed Harvest Strategy, an inter-year bio-economic simulation model of the Western Rocklobster fishery was constructed. The model was designed to explore the operation of the TACC setting control rules over a period of several decades in a fishery subject to substantial fluctuations in recruitment, quite high levels of exploitation of available legal biomass in each fishing season, and non-trivial levels of growth and natural mortality of recruits and survivors until harvested.

Particular outputs of interest from the model are the impact of discretionary values for the floor Threshold Value (TV) for closing stock biomass (CLB), and target Legal Proportion Harvested (LPH) embedded in the TACC setting control rules on:

- inter year fluctuations in the TACC,
- efficacy in maintaining fishery sustainability,
- inter-year fluctuations in the aggregate level of required effort,

- efficacy in maintaining target levels of catch rates,
- utilization of fleet capacity
- utilization of processing capacity,
- net economic returns in the catching sector
- net economic returns in the processing and marketing (P&M) sector.

The specific alternative parameter values investigated were:

- TV (CLB) = 5,000t; 10,000t; or 15,000t

- LPH = 35%; 45% or 55%

Amongst the alternative TV (CLB) settings, choosing TV (CLB) = 15,000t is the most conservative or precautionary because it provides the largest safety cushion against a worst case scenario of sustained recruitment failure. Such a high floor level for CLB also implies a very substantial initial rebuilding of stock biomass because the floor exceeds estimates of the current CLB by a very large margin. In the short run, an LPH of only 35% of available legal biomass (ALB) also is more conservative than the alternative values because it constrains increases in the TACC during periods of abundance, and thereby mitigates against rapid depletion of stock levels.

Given an assumed hard line modus operandi of the HSCR for TACC setting, the first finding from this study was that the chosen floor level of TV (CLB) was never breached over the hypothetical 46 years of simulated operation. Moreover, when TV (CLB) = 5,000t and LPH = 35% or 45% were chosen, the minimum realised CLB exceeded the floor level by a considerable margin. Conversely, when TV (CLB) = 15,000t and LPH = 45% or 55% were chosen, realized CLB was constant at the floor level for the entire 46 years. However, when TV (CLB) = 5,000t, the maximum realized CLB was about double the floor level when LPH = 55%, and more than triple the floor level when LPH = 35%. In summary, the sustainability objective of the Harvest Strategy could be achieved for all HSCR settings so long as the settings were not judged by independent analysis to be too risky, and so long as a hard line approach was implemented of setting the annual TACC to whatever level was required to preserve the chosen floor level of TV (CLB).

In the long run, the maximum TACC for any given TV (CLB) was found to increase by a modest amount as the LPH parameter increased, but for any given LPH value was relatively insensitive to the chosen floor for TV (CLB). Stability of the TACC as measured by average TACC as a percentage of maximum TACC over the 46 year evaluation period was high at about 80% for most HSCR settings, but less than 70% for TV (CLB) = 15,000t.

Stability of the TACC is a key issue with different implications for the processing and marketing sectors because the outputs from harvesting are inputs to processing. Given fluctuations in recruitment and biomass, harvests will fluctuate if catching inputs are stable, and vice versa. Thus, if a set of harvest rules entails stable catching inputs, and variable catching outputs, the processing sector has to deal with inter-annual fluctuating throughput. As a result, maintained processing capacity will need to be higher, and average processing capacity utilisation will be lower. In addition, fluctuating catch levels will potentially affect the average prices received by fishers, which are likely to be lower if the processor has to market fluctuating output.

Arguably of greater importance than stability of the TACC over the long run is the minimum level of the TACC required to preserve the chosen floor level of TV (CLB). This is because unusually low throughput may well endanger the financial viability of firms in one or both sectors of the supply chain. From this perspective, setting TV (CLB) = 15,000t involves the greatest economic risk because minimum TACC was only about 20% of maximum TACC for each level of LPH. For TV (CLB) = 10,000t, the comparable measures range from 30% to

42% for LPH = 55% to 35% respectively, while for TV (CLB) = 5,000t, the comparable measures range from 49% to 42%.

As explained above, in any given year the TACC and ALB interact to determine required fishing effort in that year, so long run maximum required annual fishing effort determines required fleet size. In this study, the required fleet size was found to increase with increasing values for LPH, but was largely invariant with respect to TV (CLB) for any given LPH except for LPH = 55%, where it was markedly smaller for TV (CLB) = 15,000t, than for lower floors to CLB.

Given fleet size, required annual fishing effort in any one year will determine the number of days the fleet needs to spend fishing in that year, with obvious implications for variable catching costs. For all LPH values for TV (CLB) = 5,000t, and for TV (CLB) = 10,000t and LPH = 35%, the fleet had to fish on all, or almost all available fishing days in each and every year. For other HSCR settings, fewer fishing days were utilised in some years, and for TV (CLB) = 15,000t and LPH = 45% or 55%, the TACC was filled in only 30% of available fishing days in at least one out of the 46 simulated years.

The sensitivity of the above findings to the assumed sequence of PSI time series was tested by limited evaluation of the impact on HSCR TACC setting rules of alternative assumptions about the future time sequence of PSI and recruitment. The results were found to be robust to the specifics of this set of assumptions.

The influence of harvest rules on levels of investment in fleet and processing capacity, and utilisation thereof, will interact with prices received by processors, and derived prices paid by processors to fishers, to determine the overall economic performance in the supply chain.

The first point to note is that net economic returns to the catching sector are surprisingly insensitive to the HSCR settings, or at least to the range of settings evaluated in this study. It seems that the HSCR settings influence the various determinants of catching sector profitability in complex ways, and that these are largely offsetting. For instance, on the one hand increasing the value for LPH tends to result in bigger average and maximum levels of TACC, and hence more revenue at constant prices. On the other hand, a larger investment in fleet capacity is needed to take advantage of the higher maximum TACCs, thereby increasing fixed costs. Conversely, larger fleets generally need fewer fishing days to catch the higher TACC, thereby decreasing variable costs. Thus, while the NPV of catching sector net economic returns is maximised when TV (CLB) = 5,000t and LPH = 45%; catching sector NPV is more than 98% of this maximum for TV (CLB) = 10,000t and LPH = 45% or 55%. Furthermore, it is more than 90% of this maximum for all of the other HSCR settings evaluated in this study.

However, average returns hide the risk of significant downturns in annual returns that might bankrupt at least some firms. This study found that more conservative strategies involving TV = 15,000t, or more exploitative strategies involving LPH = 55%, run the greatest risk of a disastrous downturn in catching sector annual financial returns. On balance then, the extremely small opportunity cost of choosing TV (CLB) = 10,000t and LPH = 45% rather than TV (CLB) = 5,000t and LPH = 45% more than justifies the much larger safety cushion in satisfying the sustainability objective by choosing TV (CLB) = 10,000t.

In contrast to the catching sector, net economic returns to the processing and marketing (P&M) sector are rather more sensitive to the range of HSCR settings evaluated in this study. This is because the sector must maintain sufficient capacity to process and market the largest likely TACC for the foreseeable future even though the size of the annual TACC determines annual throughput, as well as variable costs. In this study, estimated maximum NPV of net economic returns to the P&M sector of $481m was achieved by setting TV (CLB) = 5,000t and LPH = 55%. For the lower risk strategy of TV (CLB) = 10,000t, the next best NPV estimate was \$440m from setting LPH to 45%. Estimates of P&M sector NPV for the even lower risk strategy of TV (CLB) = 15,000t were much smaller, and in the range from \$324m to \$366m. With regard to minimum net economic returns for the worst financial year in the simulated time sequence of 46 years, it was estimated that the P&M sector would incur losses for almost all of the strategies apart from the more biologically risky strategies involving TV = 5,000t and LPH = 35% or 45%. Notably, this sector is projected to sustain significant losses that could prove financially fatal if the most conservative strategies, involving TV = 15,000t, were adopted.

In summary, so long as demand is more or less perfectly elastic, catching sector economic returns are greatest when TV(CLB) = 5,000t & LPH = 45%, but NPV for the P&M sector is \$445m, which is 7% less than the maximum possible. For this scenario, maximum possible catching sector NPV = \$1,806m is generated by a fleet of 130 boats each fishing the maximum feasible number of 250 days per year in each and every year. Hence, average catching capacity utilization equals 100%. The annual TACC for this scenario averages 9,483t, but it fluctuates from as little as 5,318t, and up to as much as 11,566t, so average P&M capacity utilization is only 82%.

Conversely, P&M sector economic returns are greatest with an estimated NPV of \$481m when TV(CLB) = 5,000t and LPH = 55%. For this scenario, catching sector NPV = \$1,797m, which is only slightly less than the maximum NPV of \$1,806m. It is generated by a fleet of 159 boats that on average fish for 249 days per year, although for at least one year in 46, the entire TACC could be caught in just 234 days, while in other years, the maximum feasible number of 250 days is needed to catch the TACC. Consequently, average catching capacity utilization is almost 100% (i.e. 249/250). The annual TACC for this scenario averages 10,340t, but it fluctuates from as little as 5,299t, up to as much as 12,756t, so average P&M capacity utilization is only 81%.

Maximum overall economic returns for both sectors, with a combined NPV of \$2,278m, is achieved when TV(CLB) equals 5,000t and LPH equals 55%. However, although these Harvest Strategy parameter values maximize combined economic returns, setting the TV(CLB) equal to 5,000t is arguably too low to satisfy the Sustainability Objective.

Arguably TV = 10,000t and LPH = 45% are the most appropriate HSCR settings. Simulated annual time series of results for this setting show two relatively short downturns in recruitment to the fishery, during which CLB fell to the floor value, and TACC had to be reduced to about 6,000t in one instance, and to about 4,000t in the other instance so as to stop CLB falling through the floor. During these periods, the season would be much shorter than the available 250 days because of low TACCs.

Findings from a supply chain analysis for West Coast Demersal Scalefish

Many demersal scalefish species (over 200) are caught in the West coast fishery. The largest catch volumes of West Australian Dhufish occur in the West Coast Demersal Scalefish (Interim) Managed Fishery, whilst this Fishery and the adjoining Gascoyne Demersal Scalefish Managed Fishery account for the largest catches of Snapper, these being the two most recognisable species.

The major species caught by volume are Snapper (479t), emperors (498t) and tropical snappers (1680t). Snapper (*Pagrus auratus*) is arguably the premier fish species for consumers seeking high quality local fillets and whole fish. The catch of Snapper is sold entirely locally. It currently commands a premium price. There is competition for Snapper from other locally caught finfish and from imported finfish, including imported Snapper.

The fishery is relative small in value with aggregate catch value of \$9-\$10million.

Locally, the major competition for Snapper is from emperors, especially red emperor (*Lutjanus sebae)* and from tropical snapper, especially Goldband Snapper (*Pristipomoides multidens*). A major potential and at times actual source of import competition is NZ Snapper (*Pagrus auratus*). These premier line caught species such as Snapper and Goldband Snapper are sold primarily through specialised fresh seafood outlets (as whole fish and fillets) and to restaurants. They, along with West Australian Dhufish and Baldchin Groper which are caught in relatively smaller volumes, command a market price premium compared to other demersal finfish species. Major supermarkets offer whole fish and fillets but focus on less expensive products such as Saddletail Snapper *(Lutjanus malabaricus*) imported from the Northern territory trawl fishery that can be sold through supermarkets at a price point competitive with other core protein foods such as chicken and red meat.

Locally caught demersal species are sold by fishers through the wholesale fish markets or direct to processors. Some fishers are dedicated suppliers to a single processor. Others choose to sell their catch entirely through wholesale markets. Those selling direct to processors have smaller monthly price fluctuations, and hence a potentially more predictable cash flow, although arbitrage possibilities ensure that the average price received by fishers do not vary to any significant extent. Processors handle a range of species, including imports. In most cases processors have their own retail outlets as well as supplying fresh fish to customers including other fresh fish suppliers, fish and chip shops, restaurants and supermarkets.

A number of processors exist in the Western Australian market. The process of filleting is relatively straightforward and essentially is the same for all species. The technology of handling fish is accessible to all. The skill is in supply chain management of processing and deliveries and management of inventory at any point in time. There are no significant barriers to entry, and in all respects, the post-harvest processing sector appears contestable. Processors tend to focus on a small range of species that suit their customer needs but the technology is such that they could easily switch species if an economic opportunity existed. This in turn suggests that the margins are competitive.

The retail sector also appears to be highly contestable. One manifestation of this is the evolution of the direct delivery business in competition with the traditional retailer. The direct distributor takes orders direct from customers (residential consumers and business consumers) for direct to your door delivery. They handle a wide range of species including premium species such as Snapper and Goldband Snapper. Insofar as premium fillets and whole fish like Snapper are concerned, although supermarkets choose not to handle them, they could easily switch to these species if the economic returns justified it.

A simple supply chain price mark-up model was applied to known beach price and retail price data to estimate the mark-ups that would translate the former into the latter. A review of the literature indicates that these mark-ups are consistent with what would be expected in a competitive post-harvest sector. They are also comparable with the Australia wide mark-ups estimated by IBISWorld for fish processing and wholesaling in Australia.

The contestability of the supply chain and the consistency of the estimated mark-ups with contestable outcomes suggest that in the long run, super normal profits could not be sustained in the post-harvest supply chain for demersal fish in Western Australia.

This being the case increasing returns to fishers arise either from increasing the retail price for the particular demersal species caught, or from lowering the harvesting costs.

Increasing the retail price requires that the demand curve for these species shifts to the right. Ceteris paribus, this would tend to increase the retail price if the fish supply curve is upward sloping. In respect of the aggregate fish supply into Western Australia, imported fish such as basa from Vietnam, make up a substantial part of the fish market. For particular premium species such as Snapper there is also competition from directly comparable fish. For example, Snapper is readily available from New Zealand at competitive prices. In the current market situation, the evidence indicates that Snapper can, and has been imported into Western Australia at prices comparable to those paid for local Snapper.

The availability of imports with high price elasticity of supply implies that a shift in the aggregate demand for fish will not shift prices as much as if no such imports existed, although any increase in price will push up the whole set of relative prices.

At any point in time, shifting the demand curve for fish is a challenge. The report investigates the potential for generic advertising to deliver an increase in the demand for fish and whether generic advertising is potentially a method to increase demand for the species of interest to this study – locally caught demersal species such as Snapper and West Australian Dhufish.

Generic advertising is typically is funded by producer based levies, and focuses on the generic product – meat, eggs and fish. Generic advertising of the product promotes the cause of all producers. It aims to shift the demand curve to the right, at the expense of competing generic products. Promoting a particular subset within a generic group (e.g. Snapper) runs the risk that the promotion would simply cannibalize the other products in the generic group (e.g. fish) because products within the group (e.g. types of eggs, or lamb or fish) are closer substitutes for products inside the group than they are for products in other food groups.

The modelling indicates that because fishers are competitive price takers, they will only gain from a generic program if the net price they receive increases, and if, after allowing for responses of market prices and quantities, producers' net returns increase. This will only happen if, and only if, the demand expansion effect of generic advertising increases the received producer price by more than the cost increasing impact of that portion of the levy finally borne by producers. The higher the price elasticity of demand the larger is the increase in sales required to secure net benefits from generic advertising.

However, Snapper and the other major species associated with the West Coast Demersal Scalefish Fishery are in limited supply and likely to be subject to even tighter harvest limits in future (see below). Hence, the scope to achieve the required positive supply response is limited.

The review of the generic advertising literature indicates that generic advertising of fish offers some potential to shift demand from substitutes products like red meat to fish. The core generic advertising message has been that health benefits are made possible by making such a switch. As such, the subject of the generic promotion is fish not a particular type of fish. A key to getting greater returns for fishers with generic promotion is a positive supply response. This is more likely to be possible in aquaculture. Hence, the available evidence of generic species promotion success pertains to salmon. Generic advertising to achieve higher prices for a particular species of a particular sub group in the presence of limited supply response and the availability of substitutes is unlikely to be successful.

Lack of a positive supply response limits the potential benefit of generic advertising of the West Coast Demersal Scalefish Fishery species in isolation. Moreover, the available evidence on substitution suggest that the various species caught in the West Coast Demersal Scalefish Fishery, in particular Snapper, have a number of very close substitutes in the market place, including Goldband Snapper, other snappers and imported fish such as New Zealand Snapper. This also suggests that the commercial fishers are not likely to be compensated for harvest restrictions through higher market prices for the restricted catch.

Given that generic advertising offers little or no scope, and that fishers are not likely to be fully compensated for restricted catch by higher prices, the remaining aspect of the chain where net returns might be increased is the harvest sector itself. Management regimes that encourage and permit fishers to become more efficient at catching and that are in themselves cost efficient are perhaps the best opportunity to increase fishers' net returns.

Formal management of the demersal catch is relatively recent. In May 2007, following a three year review of commercial wetline fishing, the Government embarked on a formal strategy to contain commercial catch and to reduce latent commercial fishing effort. From January 2008, entry permits were introduced that limited access to the West Coast Demersal Scalefish Fishery The number of potential fishers fell from 1,250 to 61. Of this reduced number of operators, the number with access to each of three of the four defined inshore 'areas' (or zones) of the fishery, was also limited.

Stock assessments indicating fish stock mortality rates for the 'key indicator' species (Baldchin Groper, Snapper and West Australian Dhufish) materially higher than the internationally recognized reference rates for this type of fishery; gave rise to concerns about the sustainability of demersal scalefish stocks in the fishery. From January 2009, numerous indirect controls built around maximum effort limits (fishing time 'capacities') to contain the demersal scalefish commercial take from the West Coast fishery were introduced. There are no direct controls over the quantum of take. This reform involved a scheme allocating entitlement to permits (in the form of units that provide entitlement expressed in fishing hours) and allowed for the transferability of both entry permits and units of entitlement.

These strategies were intended to allow the commercial demersal scalefish catch in the fishery to remain static, whilst management objectives and the future harvest strategy (including new management arrangements for the recreational sector) were determined and implemented.

The outcome is that commercial demersal fishing in Western Australia is managed under a complex array of Management Plans focussed on control of the fishing method. These apply to explicitly defined areas of the coastal waters, and, under certain Plans (e.g. West Coast Demersal Scalefish Interim Managed Fishery), to sub-sets of those waters within the fishery. On the other hand, the recreational sector's (including charter operators) use of these fisheries is managed within coastal waters falling within the defined West Coast Bioregional areas of ocean with typically no sub-sets of those waters. The respective ocean boundaries for these competing resource user sectors are not matching boundaries.

Within each commercial fishing Management Plan applying in the West Coast Bio-region, the primary management tool is the allocated fixed number of gear and time fishing entitlements. Side conditions restrict the gear that can be used and the extent of the gear that can be used by the licensed operator whilst fishing. These gear conditions vary across the ocean areas that can be fished even though the species caught can be the same and the ocean areas are proximate.

In the case of the West Coast Demersal Scalefish Interim Management Plan, minimum fishing time 'flag falls' apply each time licensed operators enter the fishery to fish and these vary across the defined areas of the fishery. Whilst licenced fishers in this fishery with entitlement unit holdings to more than one area that are contiguous may be fished simultaneously, the respective fishery 'flag falls' apply on entry to each of the areas. In addition, licensed fishers are required to lodge 'pre-trip' plans before entry and, whilst these can involve fishing in more than one area, variations at sea are not permitted without returning to port. The process for effecting changes to another fishery/area to fish for the same species and of switching gear to that which is approved for the new area to be fished require the licensed operators to return to port. These elements of the management regime essentially used up some of the allocated entitlement fishing hours and impinge on the operational efficiency of commercial operators.

Although under the management plans demersal species are managed in distinct geographic areas, there is an argument that it is essentially the same demersal scalefish stock that is being fished.

The latest stock assessments suggest that the current interim management arrangements will need on going adjustments.

The design of future management arrangements needs to take account of fisher behaviour under existing arrangements and, given the results of our analysis on other parts of the supply chain, the impact of changes on the efficiency of harvesting.

The report includes an analysis of the fishing outcomes under the 4 years of the current interim arrangements. In response to the implementation of indirect fishing controls commercial fishers typically change their fishing behaviour in ways that improve catching efficiency (within the introduced controls) to achieve the best possible net return outcome. This is typically driven by such changes as when they go fishing, where they fish, the number and duration of fishing trips, the catchability of specie(s), and, in this multi-species fishery, the specie(s) targeted.

Outcomes in the WCDS fishery since the implementation in 2009 of effort limits (fishing time) in this fishery have been no exception. The analysis of the reforms shows efficiency improving outcomes in the form of increased kilograms of fish caught for each hour fished of almost 6% over the period to 2012 for the fishery. This is most evident in the Mid-West inshore area with continuous improvements amounting to 37% over the period. The Kalbarri area also exhibited a notable initial improvement as well, but this slipped away in 2012 resulting in only a modest 5% improvement over the 2009 level. The South West inshore area also exhibited a notable initial improvement but this also slipped in 2011 and 2012 and at the end was noticeably less than the 2009 level. Ongoing use of complex effort controls based on hours with side conditions relating to areas and gear will almost certainly impact both on fishing cost effectiveness and also on the actual cost of management. However, given the ability of fishers to respond by becoming more efficient, may not achieve desired catch levels. A review of actual current management plan components and of potential actions indicates that scope exists to consider a greater reliance on direct output controls as well as to simplify arrangements with respect to fisher spatial definitions and gear requirements.

Lessons learned from a supply chain approach

The overriding lesson learnt from this study is that, at least for these two fisheries, the markets in which the post-harvest sectors of the supply chains operate are very much contestable and competitive. Consequently, there is little scope to improve economic returns to the fishery by direct intervention into operations in these parts of the supply chain, or to increase demand for fish generally, or even for certain species of fish..

Almost all of the catch of Western Rocklobster (WRL) is exported to Greater China (GC), with much smaller amounts to other overseas markets. In all of these markets, it faces strong competition from many related types of lobster, all of which are quite close substitutes for WRL. Some of these related lobsters attract a price premium over WRL, while others sell at a discount, but all lobster prices tend to move more or less in parallel because they are such close substitutes. Moreover, because the supply of WRL to GC accounts for a very small part of supply of all lobster to this market, the long run demand for WRL is extremely elastic. Hence, in the long run controlling supply of WRL to these markets will have minimal effect on prices.

The market for West Coast Demersal Scalefish is principally a local market, but nevertheless also is very much contestable and competitive. Competition comes both from the supply of the same or closely related species from other WA fisheries (e.g. Pilbara); and from imports of the same or closely related species from other inter-state and overseas fisheries, especially NZ. Consequently, controlling supply of West Coast Demersal Scalefish to the local market again will have minimal effect on prices in the long run. Nor will generic promotion be likely to increase returns in the supply chain.

While the post-harvest sectors of the supply chains for both fisheries are highly contestable, clearly the respective catching sectors are manifestly not fully contestable because they are entry controlled with input or catch restrictions. If there is little scope to improve economic returns by direct intervention, such as generic promotion, in post-harvest parts of the supply chain, it follows that the best prospects for enhancing economic returns in each fishery is by more efficient governance of the catching sector. Clearly, maintaining the historical pre-eminent focus of fisheries governance on biological sustainability of the fishery is a prerequisite for efficient management. However, subject to satisfying this sustainability requirement, identifying opportunities to make fishery governance more efficient by reducing the costs of management and or improving economic returns to fishing, by providing commercial operators with as much flexibility as is compatible with biological sustainability, deserves to be examined more closely.

For fisheries like the WCRLF that have implemented a strong property rights based governance framework, the findings from analysis of the choice of alternative HSCR parameter values on economic returns in the supply chain is illustrative of the scope for further work. Results that are more definitive would require development of a stochastic bio-economic simulation model, with a more realistic population dynamics component, that could be used to carry out a Monte Carlo evaluation of the riskiness of a more comprehensive range of harvest strategies, and to investigate intra-year as well as inter-year ramifications of alternative TACC setting control rules.

In fisheries like the WCDSF, effective and efficient means of controlling both the commercial and recreational catch is an ongoing challenge. If harvest objectives and resource sharing targets are to be realized in a way that optimizes economic benefits to Western Australian community, there seems to be a case for some fundamental reforms to the governance structure based on a comprehensive assessment of the pros and cons of introducing an ITQ based system vis-à-vis refinements to existing effort control systems.

Conclusions

Fisheries managers seek to optimize the social value of the fish resource through managing and licensing fishing activities and by protecting the environment and ecosystems on which fish depend. In so doing they create relationships between government and market agents (producers, processors, marketers, customers) along the supply chain. The mix of contractual relationships along the chain can be viewed as a governance structure. It is a mix of internal and external governance. External governance is embedded in the fishery management arrangements. It regulates behaviours and influences the relationships between private sector agents in harvesting, processing and marketing. Internal management is embedded in the contractual arrangements between privet sector agents. The relationships within this governance structure are an important determinant of overall economic performance.

The principal components in fishery supply chains are the catching, processing and marketing sectors. Stable and well structure governance arrangements across all sectors are required to achieve optimal economic outcomes. For example, to develop long term marketing strategies and make efficient investments in processing capacity, the processing sector requires a reliable and consistent supply of fish. This processing investment will, in turn, give the catching sector the stability to optimize its operations and investments. Government involvement (external governance) can enhance value through harvest strategies and potentially, marketing. Harvest strategies ensure that harvests are biologically sustainable and can enhance economic performance of the supply chain, by encouraging fishers to harvest the designated catch with maximum efficiency. Some marketing interventions, such as country of origin labelling, marketing and certification for local produce, can potentially enhance value by encouraging consumers to demand local produce and pay more for it.

This study investigated governance arrangements within a supply chain framework for the Western Rocklobster Fishery and the West Coast Demersal Scalefish Fishery. The focus was using supply chain analysis to understand how value is crated for the resource and how governance arrangements impact or might impact on value. In this way, external governance strategies that government might implement to enhance value can be identified.

The Western Rocklobster fishery (WCRLF), is managed using individual transferable quotas (ITQs). This is a recent transformation away from effort controls and as part of this process, a Harvest Strategy is being developed that at its core, will comprise a set of decision control rules for annually setting the Total Allowable Commercial Catch (TACC). The Harvest Strategy and Control Rules (HSCR) framework incorporates a sustainability objective that sets a floor "threshold value" to egg production capacity with the aim of maintaining stock biomass at levels last experienced in the mid-1980s. To increase lobster abundance, reduce catching costs, and increase economic returns the rules will fix the TACC at a conservative level so as to limit the Legal Proportion Harvested (LPH) to some maximum proportion, and thereby build catch rates to a target level.

These are significant changes to industry governance structure, and there is considerable uncertainty about how such changes will impact on the operations and profitability of the various sectors in the supply chain over time.

To enable investigation of some of the consequences of the proposed Harvest Strategy, an inter-year bio-economic simulation model of the Western Rocklobster fishery was constructed. Western Rocklobster is almost entirely exported and the post harvest, processing, shipping and marketing are typically integrated in one firm. The model was designed to explore the operation of the TACC setting control rules over a period of several decades allowing for the documented substantial fluctuations in recruitment, quite high levels of exploitation of available legal biomass in each fishing season, and non-trivial levels of growth and natural mortality of recruits and survivors until harvested. The model evaluates the impact of discretionary values for the floor Threshold Value (TV) for closing stock biomass (CLB), and target Legal Proportion Harvested (LPH) embedded in the TACC setting control rules on key variables biological and economic outcomes for the fishery. It does this for TV (CLB) values of 5,000t, 10,000t and 15,000t and for LPH values of 35%, 45% and 55%.

From a biological perspective, assuming a rigorous implementation of the HSCR for TACC setting, the chosen floor level of TV (CLB) was never breached over the hypothetical 46 years of simulated operation. The sustainability objective of the Harvest Strategy could be achieved for all HSCR settings so long as the settings were not judged by independent analysis to be too risky, and so long as a hard line approach was implemented of setting the annual TACC to whatever level was required to preserve the chosen floor level of TV (CLB).

Stability of the TACC is found to be a key issue with different implications for the processing and marketing sectors because the outputs from harvesting are inputs to processing. Given fluctuations in recruitment and biomass, harvests will fluctuate if catching inputs are stable, and vice versa. Thus, the harvest rules produce stable catching inputs, and variable catching outputs, the processing sector has to deal with inter-annual fluctuating throughput. As a result, processing capacity will need to be higher, and average processing capacity utilisation will be lower. In addition, fluctuating catch levels will potentially impact upon average prices received which are likely to be lower if the processor has to market fluctuating output. Beyond the stability of the TACC over the long run, there is the further issue of the minimum level of the TACC required to preserve the chosen floor level of TV (CLB). If the harvest rules cause unusually low throughput at any point in time this may well endanger the financial viability of firms in one or both sectors of the supply chain.

From this perspective, setting TV (CLB) = 15,000t involves the greatest economic risk because minimum TACC was only about 20% of maximum TACC for each level of LPH. On the other hand for TV (CLB) = 5,000t, the minimum TACC was between 42% and 49% of maximum TACC.

The influence of harvest rules on levels of investment in fleet and processing capacity, and utilisation thereof, will interact with prices received by processors, and derived prices paid by processors to fishers, to determine the overall economic performance in the supply chain.

In contrast to the catching sector, net economic returns to the processing and marketing (P&M) sector are rather more sensitive to the range of HSCR settings evaluated in this study. This is because the sector must maintain sufficient capacity to process and market the largest likely TACC for the foreseeable future even though the size of the annual TACC determines annual throughput, as well as variable costs.

Across the two sectors, so long as demand is more or less perfectly elastic, catching sector economic returns are greatest when TV(CLB) = 5,000t & LPH = 45%, but under this setting the NPV for the P&M sector is estimated at $445m, which is 7% less than the maximum possible. For this scenario, maximum possible catching sector NPV = $1,806m is generated by a fleet of 130 boats each fishing the maximum feasible number of 250 days per year in each and every year. Hence, average catching capacity utilization equals 100%. The annual TACC for this scenario averages 9,483t, but it fluctuates from as little as 5,318t, and up to as much as 11,566t, so average P&M capacity utilization is only 82%.

Conversely, P&M sector economic returns are greatest with an estimated NPV of $481m when TV(CLB) = 5,000t and LPH = 55%. For this scenario, catching sector NPV = $1,797m, which is only slightly less than the maximum NPV of $1,806m. It is generated by a fleet of 159 boats that on average fish for 249 days per year, although for at least one year in 46, the entire TACC could be caught in just 234 days, while in other years, the maximum feasible number of 250 days is needed to catch the TACC. Consequently, average catching capacity utilization is almost 100% (i.e. 249/250). The annual TACC for this scenario averages 10,340t, but it fluctuates from as little as 5,299t, up to as much as 12,756t, so average P&M capacity utilization is only 81%.

Maximum overall economic returns for both sectors, with a combined NPV of $2,278m, is achieved when TV(CLB) equals 5,000t and LPH equals 55%. However, although these Harvest Strategy parameter values maximize combined economic returns, setting the TV(CLB) equal to 5,000t is arguably too low to satisfy the Sustainability Objective.

The study finds that a setting of TV = 10,000t and LPH = 45% are the most appropriate HSCR settings. Simulated annual time series of results for this setting show two relatively short downturns in recruitment to the fishery, during which CLB fell to the floor value, and TACC had to be reduced to about 6,000t in one instance, and to about 4,000t in the other instance so as to stop CLB falling through the floor. During these periods, the season would be much shorter than the available 250 days because of low TACCs.

In contrast to the Western Rock Lobster Fishery, the West Coast Demersal Scalefish Fishery is multispecies (.200) and the catch is sold locally.

The major species caught by volume are Snapper (479t), emperors (498t) and tropical snappers (1680t). Snapper (*Pagrus auratus*) is arguably the premier fish species for consumers seeking high quality local fillets and whole fish. The fishery is relative small in value with aggregate catch value of $9-$10million. The catch of Snapper is sold entirely locally at a premium price. There is competition for Snapper from other locally caught finfish and from imported finfish, including imported Snapper.

Unlike lobster, there is as yet no fully developed biological model that can form the basis of an integrated bio economic model of the supply chain. For this fishery, a multi stage price mark-up model was applied to known beach price and retail price data to estimate the mark-ups that would translate the former into the latter. The estimated mark ups are found to be consistent with what would be expected in a competitive post-harvest sector. They are also comparable with the Australia wide mark-ups estimated by IBISWorld for fish processing and wholesaling in Australia.

Analysis of the number of fishers, processors and retailers, of operating costs, prices paid and margins confirm that the post-harvest supply chain is contestable. This finding suggest that that in the long run, super normal profits could not be sustained in the post-harvest supply chain for demersal fish in Western Australia. An important implication of this finding is that enhancing returns to fishers is then conditional on either increasing the retail price for the particular demersal species caught, or by increasing harvest efficiency and lowering the harvesting costs.

At any point in time, shifting the demand curve for fish is a challenge. An analysis is made of the of the potential for generic advertising to deliver an increase in the demand for fish and whether generic advertising is potentially a method to increase demand for the species of interest to this study – locally caught demersal species such as Snapper and West Australian Dhufish. The study concludes that increasing net returns to producers through generic advertising is unlikely for two reasons. First, modelling of generic advertising indicates that will only happen if there can be a positive supply response and second the higher the price elasticity of demand the larger is the increase in sales required to secure net benefits from generic advertising. Currently fishers are having effort reduced a as a means of controlling catch and for there are readily available subsists for the major species , such as Snapper, caught in the West Coast Demersal Scalefish Fishery. An important implication of the results is that fishers are not likely to be fully compensated for restricted catch through higher prices. These findings are shown to be consistent with evidence on advertising and prices in overseas fisheries.

Combined, these results suggest that for this fishery, the most likely source of increased returns to fishers is harvest sector operation and governance. An extensive review of the current system of management plans, geographic boundaries and input controls, was undertaken alongside an analysis of outcomes in the fishery since the implementation of effort limits in 2009. Based on this analysis, the study concludes that greater reliance on direct output controls as well as a simplification of spatial boundaries and gear requirements offers the most scope to improve efficiency and lower management and catching costs.

Overall, the results show that supply chain analysis is a valuable framework for investigating governance and overall performance. By systematically understanding how each element of the chain affects overall performance, managers are better placed to understand where effort should go in the search to improve economic performance and returns to fishers, whilst at the same time sustaining the biomass in the broader interest of the community.

Implications

There are potentially significant implications emanating from both analyses.

With respect to the Western Rocklobster fishery, results from analysis of the proposed harvest strategy using the integrated model highlight the importance of choosing the best parameter values for the TACC setting control rules. Specifically, the economic implications for both the catching and processing sectors of the chosen parameter values for the Threshold Value (TV) for biological sustainability of the stock biomass over time, and the harvest rules with respect to Legal Proportion Harvested (LPH), need to be carefully evaluated. The analysis also shows the extent to which adherence to these rules over time in the presence of a stochastic PSI will necessitate an annual TACC that can fluctuate quite dramatically on an annual basis. In turn, this is connected to how conservative managers wish to be with respect to protection of the biomass. However, the extent of the required fluctuations in the TACC is sufficiently great that the impacts on profits for catchers and processors is likely to be difficult to manage for the industry insofar as marketing is concerned, and maintaining relationships in the major export markets. The results indicate that a specific risk analysis that incorporates both biological and economic considerations is needed before rules are signed off. While incorporating caps on the maximum adjustment to TACC in any one year is likely to give a more stable pattern of sales and economic net returns, it might require choice of a higher threshold level of egg production to be made consistent with biomass security, with adverse impacts on economic returns.

The finfish case is somewhat different. Fishers in this industry, as well as other commentators, have commented that the potential must exist to improve returns. The results indicate that the most promising part of the supply chain to alter in a way that will increase returns to fishers in the management of the catching sector itself.

The evidence assembled suggests that the major species of interest, Snapper, is already primarily being delivered to its highest value uses, namely as fillets and whole fish, to final consumers; and that prices are being received at the high end of fresh fish prices in the retail sector. Moreover an analysis of margins suggest that margins in processing, wholesaling and retailing are consistent with competition and contestability in these sectors and with margins reported generally.

While it is the case that accurate labelling as to species and origin should be promulgated in respect of all fish sold, there is no clear evidence that this alone would increase demand or willingness to pay. The reason for this is that all the catch is currently sold locally because that maximizes returns, and given the premium price received, retailers have an adequate incentive to promote the accuracy of descriptions of Snapper. Generic advertising is suggested as way to promote fish consumption. Generally, generic advertising promotes a generic food product in competition with broad substitutes. Good examples are egg promotion and lamb promotion. Generic advertising of fish is used to encourage a switch to a healthier diet.

Typically, such advertising does not focus on a subset of the product class (e.g., it does not promote a particular type of egg or cut of lamb). It also promotes product in a situation where a relatively elastic supply response is expected so that if generic advertising shifts the demand cure to the right producers offer more product to the market and any price increase is modest. Promoting a local species of fish such as Snapper appears to violate these criteria. In particular if the supply is fixed, and potentially declining, such a promotion is primarily designed to secure a price increase. In addition, the analysis makes it clear that this is unlikely given the quality and range of close substitutes, both locally caught and imported.

Insofar as the catching sector goes, the analysis suggests that improvements in harvest efficiency are the logical place to look for improved returns to fishers. These opportunities will be heavily influenced by the future circumstances with respect to biomass recovery and harvest regulations.

Potential changes that could enhance catching sector efficiency include moving to tradable catch quota on individual species and away from input controls based on time, as well as reconsidering the definitions of the fishery to have a demersal species rather than a complex geography and species and gear mix strategy as currently exists.

Recommendations

Further development

In both of the case studies covered in this study, Western Rocklobster and West Coast Demersal Scalefish, a range of management changes are evolving, and will continue to do so. The results from this study can feed directly into the discussions regarding the harvest rules to be adopted in Western Rocklobster as well as the approach that will ultimately be taken to management in the West Coast Demersal Scalefish fishery. As these changes evolve and management rules are refined, there may be a need to recalibrate aspects of the models to allow for the evolved rules.

More specifically, if results indicating that improving returns to fishers in the West Coast Demersal Scalefish are likely to be best achieved through a focus on improving catch efficiency and reducing the complexity and cost of management plans, specific work will be needed on a range of topics. Most particularly work will be needed on the potential to use quota in this multi species fishery as a way of efficiently reconciling the need to achieve greater harvest efficiency with the need to sustain stocks at the designated target level.

The Western Rocklobster model illustrates the extent to which harvest will be variable on an annual basis in the presence of the specific harvest rules proposed. These rules effectively set TACC and legal proportion harvested on an annual basis.

The institution of the ITQ management regime has allowed a much greater degree of flexibility in matching production to the market. However, while the model developed here allows an understanding of the way that harvest rules impact on TACC setting and on the pattern of supply chain surpluses and biomass over years, the industry also needs to optimize the pattern of catching and processing within any given year.

As a next step, the industry could consider developing an intra-year model, similar to the inter-year model developed in this study, to focus on the impact that harvest rules might have on annual surpluses as the P&M sector attempts to optimise returns by shifting the pattern of monthly or weekly prices and catch.

Extension and Adoption

During the project, seminars were presented on the modelling. These were primarily at the Marine Research laboratories in Western Australia to elicit feedback on model structure and approach. Subsequent to the submission of the draft report presentations were made to fishers, managers and processors at a series of seminars.

The full seminar/presentation list is provided below.

Date	Location	Attendees
Oct 14 2014	Geraldton	Department of Fisheries' Annual Management Meeting. Attending; fishers, managers, WAFIC representatives. Chair Angus Callander Executive Officer Industry Consultation Unit Western Australian Fishing Industry Council
Sept 25 2014	Department of Fisheries Head office	Fishery Governance and Regulatory System Workshop. Results from FRDC 2011 203. Workshop 1. Presentation of management implications for rocklobster management. Attendees; managers of the Western Rocklobster fishery.
Sept 25 2014	Department of Fisheries Head office	Fishery Governance and Regulatory System Workshop. Results from FRDC 2011 203. Workshop 2. Presentation of management implications for West Coast Demersal Scalefish fishery management. Attendees: managers of the scalefish fisheries.
11 August	GFC Fremantle	Presentation of revised draft report results pertaining to rocklobster, and the impact of different demand parameters. Attendees: CEO and marketing managers.
28 Feb 2014	GFC Fremantle	Presentation of draft report results pertaining to rocklobster, and impact of different harvest rules on harvest and processing surpluses. Attendees: CEO, Board and senior managers.
13 November 2013	Australian Export Grains Innovation Centre	Presentation of modelling rock lobster and finfish supply chain. Attendees: supply chain researchers from AEGIC
26 July 2013	Marine Research	Supply chain analysis of WRL harvest strategies

	Laboratories, Hilarys	

Appendices

Appendix 1 References

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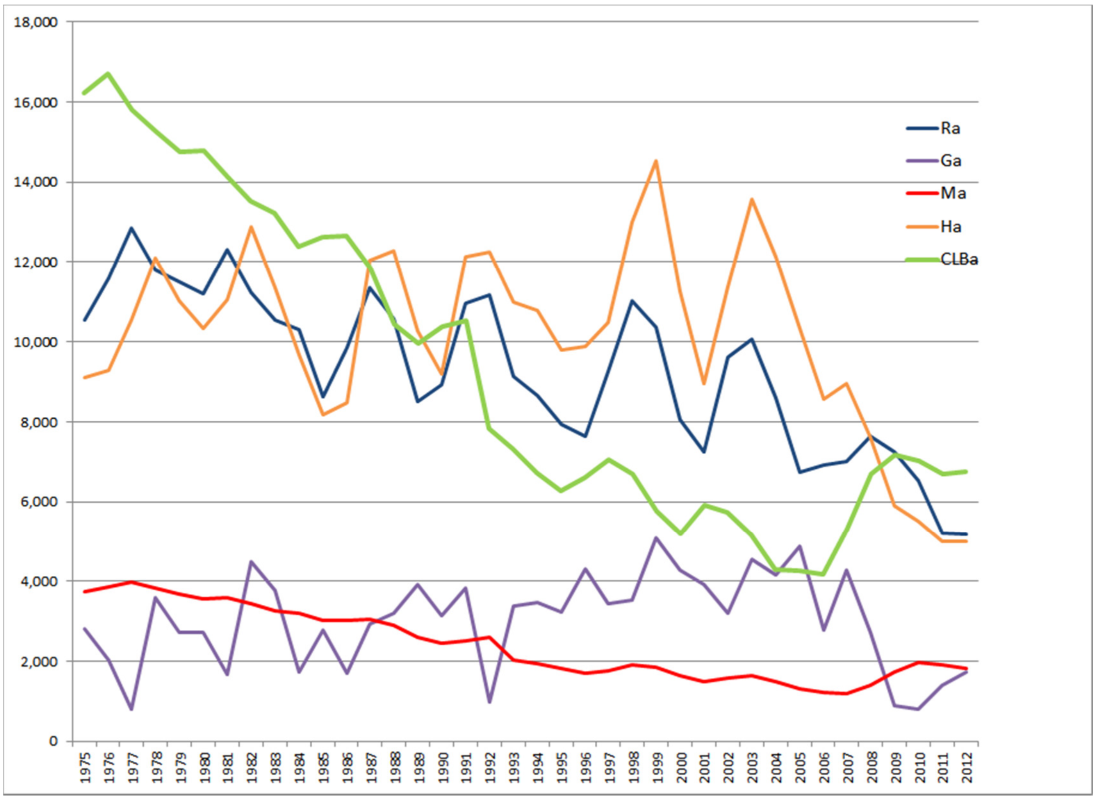
Appendix 2: Estimation of functions in the simulation of WRLF population dynamics

The population dynamics component of the bio-economic simulation model is built around the following state transition equation:

- $CLB_t = OLB_t + R_t + G_t - M_t - TACC_t$ and
- where:
  - OLB_t = Opening legal biomass in year t = CLB_{t-1}
  - R_t = Recruits to legal biomass in year t from the pool of sub-legal juveniles
  - G_t = Growth of "survivors" in year t
  - M_t = Natural mortality in year t
  - $TACC_t$ = Total allowable commercial catch in year t as determined by the HSCR
  - CLB_t = Closing legal biomass in year t

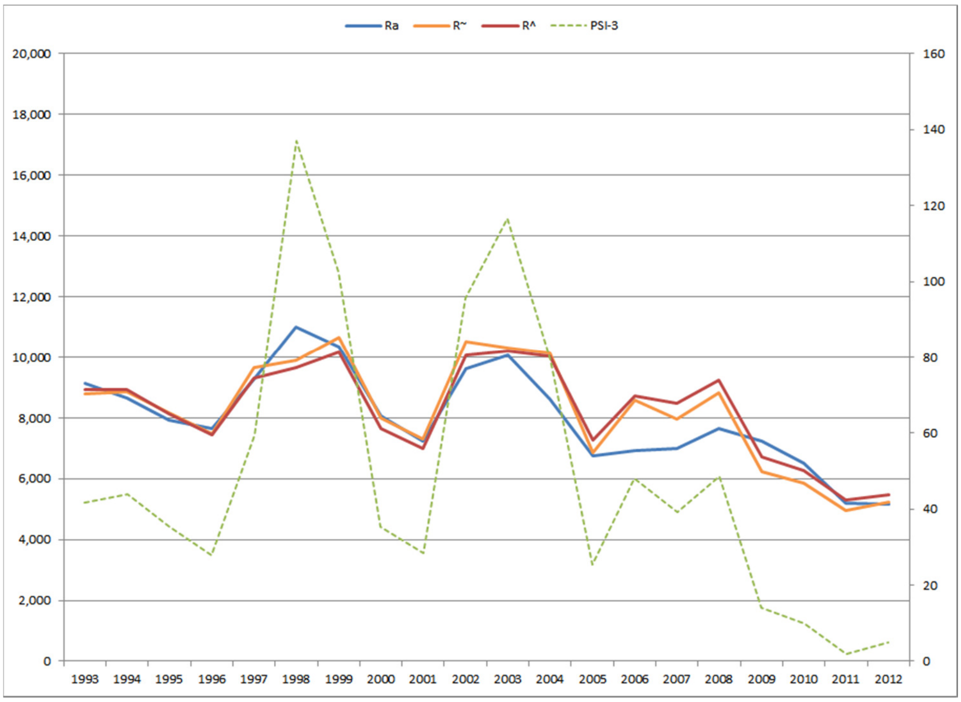
The variables R_t, G_t, and M_t are endogenous to the population dynamics model. Their functional form was estimated from data comprising outputs from the very detailed, complex, and sophisticated Department of Fisheries biological model. The time series of this data set is illustrated in Figure 57.

Figure 57 Department of Fisheries biological model outputs used to estimate functions for R_t, G_t, & M_t



A wide variety of different specifications of the functions for the variables R_t, G_t, and M_t were evaluated, both for goodness of statistical "fit", and for how well they performed as a sub-component in the population dynamics model. In particular, a key consideration was the ability to track the historical time series of Closing Legal Biomass (CLB_t) estimated from the Department of Fisheries biological model with endogenously generated values from the much simpler population dynamics model when actual historical values for $TACC_t$ were used together with a time series of the actual puerulus settlement index (PSI) values over the same time period. The functions finally chosen are detailed below.

Figure 58 Recruitment function $R_t = 3{,}100 + 0.3*OLB_t - 0.00001*OLB_t^{\wedge 2} + 120*PSI_{t-3} - 0.6*PSI_{t-3}^{\wedge 2}$

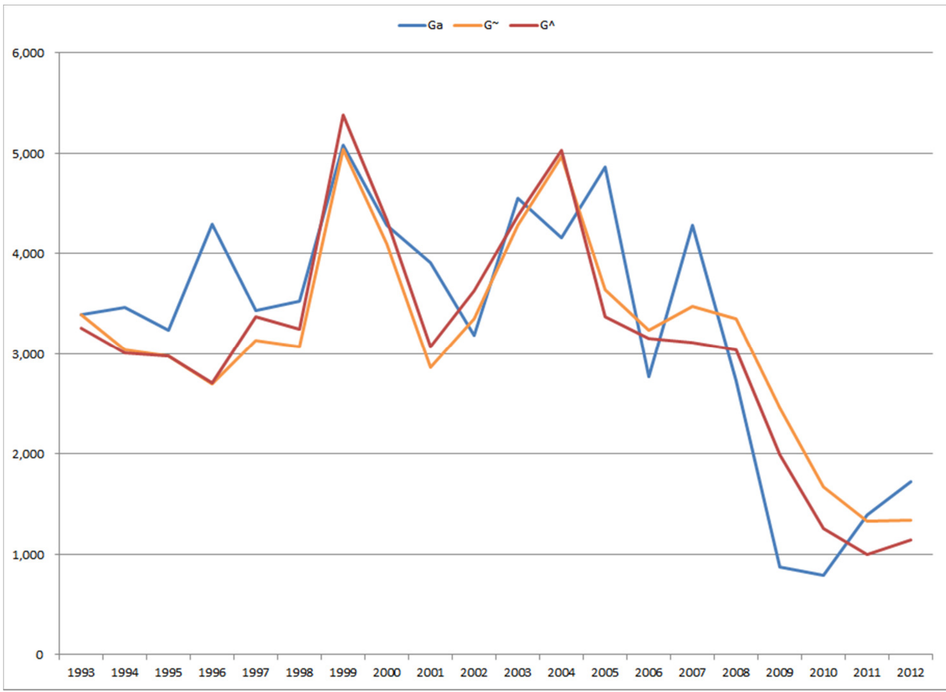


The estimated recruitment function is quadratic in OLB_t and in PSI_{t-3}, which is the puerulus settlement index lagged three years. The PSI time series had similar, but not identical characteristics to the actual PSI time series for the past 40 years. The functional form for recruitment used in the model is:

$R_t = 3{,}100 + 0.3*OLB_t - 0.00001*OLB_t^{\wedge 2} + 120*PSI_{t-3}-0.6*PSI_{t-3}^{\wedge 2}$

Figure 58 depicts the "observed" data on recruitment, R_a, from the DoF model, together with values $R^{\sim}$ predicted from this data by the above functional form, and simulated values $R^{\wedge}$ from the simple simulation model.

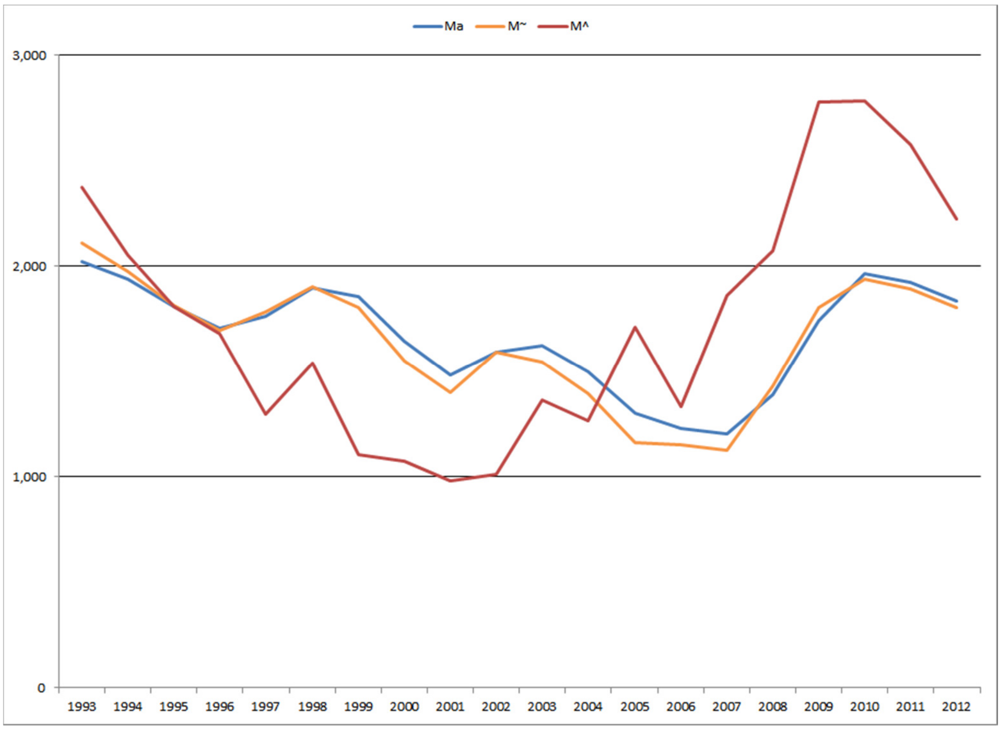
Figure 59 Growth function $G_t = 2{,}000 - 0.1*OLB_t + 40*PSI_{t-3}-0.2*PSI_{t-3}^{\wedge 2} + 17*PSI_{t-4}$



The estimated growth function is linear in OLB_t and in PSI_{t-4}, but quadratic in PSI_{t-3}. The functional form for the growth function used in the model is:
$G_t = 2{,}000 - 0.1*OLB_t + 40*PSI_{t-3}-0.2*PSI_{t-3}^{\wedge 2} + 17*PSI_{t-4}$

Figure 59 depicts the "observed" data on growth, G_a, from the DoF model, together with values $G^{\sim}$ predicted from this data by the above functional form, and simulated values $G^{\wedge}$ from the simple simulation model.

Figure 60 Natural mortality function $M_t = 0.27*OLB_t$



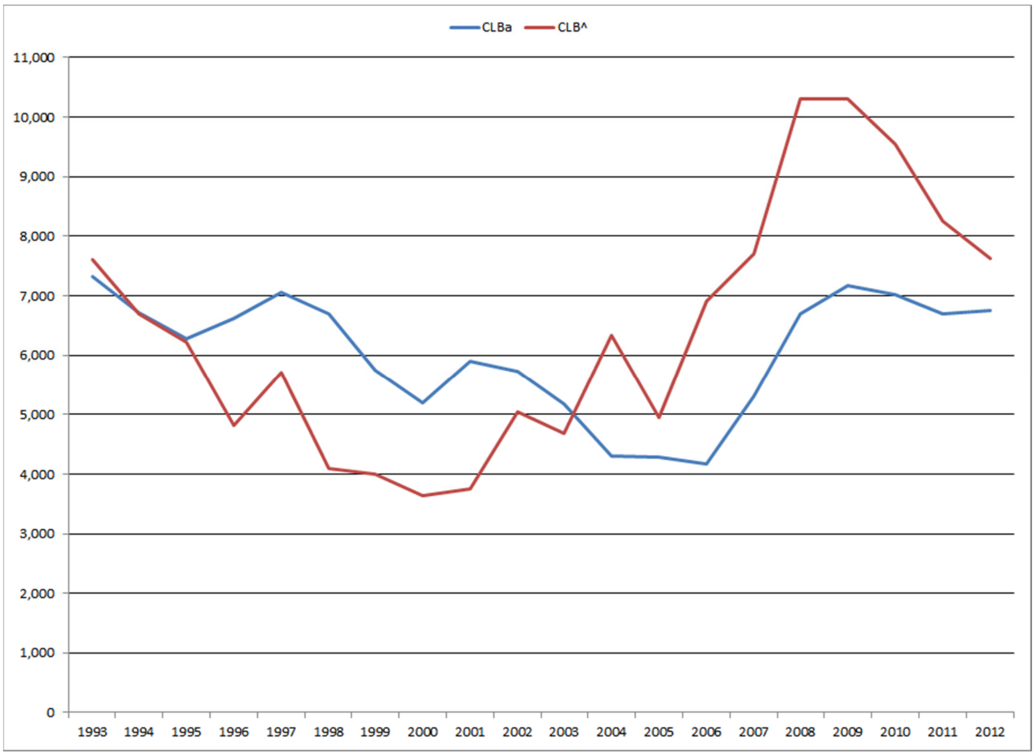
The estimated natural mortality function is linear in OLB_t. The functional form for the natural mortality function used in the model is:
$M_t = 0.27*OLB_t$

Figure 60 depicts the "observed" data on natural mortality, M_a, from the DoF model, together with values $M^{\sim}$ predicted from this data by the above functional form, and simulated values $M^{\wedge}$ from the simple simulation model.

Last, Figure 61 depicts the "observed" data on closing legal biomass (CLB_a) from the DoF model, together with endogenously generated simulated values $CLB^{\wedge}$ from running the simple simulation model with actual historical values for $TACC_t$ were used together with a time series of the actual puerulus settlement index (PSI) values over the same time period.

Modelled $CLB = CLB_t = OLB_t + R_t + G_t - M_t - TACC_t$

Figure 61 CLB from simple model versus DoF model output of CLB



Appendix 3: Investigators and Researchers

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