# DYNAMIC MODELLING OF THE SOCIALLY OPTIMAL ALLOCATION OF FISH RESOURCES BETWEEN COMMERCIAL AND RECREATIONAL USE.

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**August 2006**

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ECONOMIC RESEARCH ASSOCIATES

Australian Government
Fisheries Research and Development Corporation

Project No. 2003/039

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# Dynamic Modelling of the Socially Optimal Allocation of Fish Resources Between Commercial and Recreational Use

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The Fisheries Research and Development Corporation plans, invests in and manages fisheries research and development throughout Australia. It is a federal statutory authority jointly funded by the Australian Government and the fishing industry.

ISBN 0-9756020-3-9

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August 2006

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# 2003/039 Dynamic Modelling of the Socially Optimal Allocation of Fish Resources Between Commercial and Recreational Use[1]

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## Objectives

The overall objective of this project was methodological.

First, it sought to develop a general dynamic model that would allow an analysis of the socially optimal resource allocation through time based on changes in the marginal net benefits of commercial and recreational fishing.

Second, it sought to develop this framework so that the changes in marginal net benefits could be estimated by relating them to changes in significant socio-economic variables that drive the changes. The objective was to avoid the need for frequent direct estimation and re-estimation of marginal net benefits based on repeating contingent valuation surveys of recreational fishers and revenue and cost surveys for commercial fishers.

Finally, the dynamic framework and the approach to measuring changes in marginal net benefits over time were tested using three case studies. The three case studies were a metropolitan crab fishery, a metropolitan abalone fishery and a demersal 'Wetline' fishery. The case studies were the same ones that were used in earlier FRDC supported research by McLeod and Nicholls[2].

The first two objectives are addressed in Part One, The General Theoretical Framework of this research report, whilst the results of the three case studies can be found in Parts Two, Three, and Four of the report.

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[1] This study concentrated on the socially optimal allocation between commercial and recreational use. The methodology developed could be readily applied to other competing passive and non passive use of fish resources.

[2] McLeod P and Nicholls, 'Socio-Economic Valuation of Resource Allocation Options between Commercial and Recreational Sectors' (2004).

# NON TECHNICAL SUMMARY

## OUTCOMES ACHIEVED TO DATE

As set out in the original planned outcomes, the actual outcomes from this research (model and case study results) proved to be consistent with allowing fisheries managers to take a planned strategic approach to resource allocation. The results indicate that adoption of the final project outputs will assist resource allocation decision making by identifying socially optimal resource allocations through time.

The results indicate that application of the model will enable fisheries management to make better informed allocation decisions today because they will be a position to consider the likely pattern of future socially optimal allocations based on a systematic analysis of trends in key socio economic variables that drive changes in underlying commercial and recreational use values. An important outcome of this is that the risks of erroneous or sub optimal short term allocation changes that could require reversal in the future can be minimized. Where the model indicates a unidirectional on-going adjustment in allocation in future years and quantifies it, the overall change can be planned such that the resource and social costs of adjustment are minimized. Where the model indicates that an initial change may need to be revered in future this can be taken into account when planning adjustments today.

The potential value of the model has been illustrated in seminars given on the use of the model at the Western Australian Department of Fisheries. The Integrated Fisheries Allocation Advisory Committee in Western Australia requested a presentation of the model and the abalone case study results so that they could take the model and its results into account in determining the policy for the allocation of abalone in Western Australia. Seminars were also held for the Western Australian Fishing Industry Council.

Managers from the New Zealand Ministry of Fisheries attended a presentation of the model and results at the “Share the Fish 06” Conference in Fremantle and subsequently requested the full documentation to consider what lessons they could learn for application to their own fisheries. With approval from FRDC they were sent a copy of the complete final draft report.

### *The Need*

The research fulfils a substantive and practical need at a State and National level for an allocation model that can provide sound and reliable insights into the likely future direction of socially optimal allocations.

Allocation decisions are significant for fishery participants, including managers. Reallocation produces both gains and losses because reallocation within the constraints of a defined total sustainable harvest is a zero sum game. It is a major public policy decision. Allocation decisions can be expensive to implement and administer, they are potentially disruptive for those losing allocation and they raise the potential for significant conflict and disputation.

Allocation needs to be considered as a strategic decision that is part of the long term management of a fishery. This requires that consideration be given to the likely future pattern of allocation when framing an allocation policy or strategy. The current allocation decision made today can then be looked at in the context of the future issues in allocation. Consider a simple example. Suppose an analysis of the marginal net benefits associated with commercial and recreational fishing suggest that fish should be reallocated to the commercial sector today. Suppose that we also had reason to believe that changing circumstances in the near future would reduce the value of the fish in commercial use relative to recreational use. This could indicate that fish stocks would then be subsequently reallocated to the recreational sector in the near future thus reversing the initial allocation adjustment. If this were known and the time period was short enough it may not be worthwhile making the initial re-allocation to the commercial sector. From society's perspective we wish to optimize the allocation over time and this needs to be done taking account of any adjustment costs associated with reallocations.

The dynamic modelling in this study is designed to meet the need for this forward looking information on allocation but in such a way that we can avoid the need for frequent expensive surveys of recreational and commercial fishers.

It is aimed at satisfying the desire of fishery managers and stakeholders to know where the socially optimal allocations might be tomorrow so that they can make the best possible allocation decisions today.

***The Framework Principles***

In economic theory, the socially optimal allocation of a defined total sustainable catch occurs where the marginal net benefits to society from commercial and recreational use are equal. There is no other allocation within that total sustainable catch where the net benefits from combined use will be greater. These marginal net benefit values and their identification and estimation were explained in earlier research[3].

[3] Op cit 1

The basic idea behind the current research is that the marginal net benefit schedules for commercial and recreational fishing will change over time and that as this occurs optimal allocations will need to be adjusted to maintain equality between the marginal net benefits from commercial and recreational fishing.. The research focuses on the key variables that drive changes in the relative marginal net benefit values over time and the way in which these drivers can be measured and incorporated into a dynamic model that allows the estimation of the socially optimal allocation path for the fish resource over time.

***The Dynamic Model***

The model is based on the notion of a defined total allowable catch that will be in existence over time and which is to be allocated optimally between commercial and recreational sectors at any point in time in a zero sum game.

The basic concept underpinning the analysis is the idea that the marginal net benefit schedules for commercial and recreational fishing shift over time in a way that can be estimated based on some key variables that capture changes in the underlying circumstances in the commercial and recreational sides of the market. Model development was considered in three parts.

First, the key variables that drive changes in marginal net benefits for recreational and commercial fishing over time were to be identified.

Second, the way that these key drivers influence changes in marginal net benefits over time was modelled in a way that was sufficiently general to allow application across all three case study fisheries and ready application to other fisheries. The modelling needed to be in terms of variables and information that fisheries managers could access without having to undertake expensive re-surveying of commercial and recreational fishers every year in order to update the estimates of the marginal net benefits associated with commercial and recreational fishing. Using the proposed modeling framework, this sort of recalibration need only occur at longer intervals.

Third, the various relationships needed to be represented in a relatively straightforward model that captured the key relationships and could optimize the allocation of the sustainable catch in the presence of changes in the marginal net benefits and hence give an estimate of the shape of the time path of allocation adjustment over time.

The first fits neatly within the demand and supply framework and its application to commercial and recreational activities outlined in previous research[4]and recognises the close symmetry that exists between the key variables on either side. The second fits well with those models in economics which focus on relative growth rates for net benefits as part of benefit cost analysis of policy evaluation.

The dynamic model presented here is not designed to specify optimal solutions in terms of exact timing and quanta of future stock re-allocations. Rather the model is designed to provide helpful insights into the likely future direction of the socially optimal allocations over time which will allow fisheries managers and stakeholder to think strategically when making stock allocation decisions today.

### *The Case Study Results*

The analytical outputs from all three case studies showed that the dynamic model developed in the current study can be usefully applied. The results provide insights into likely future direction of socially optimal allocations in each of the case study fisheries and illustrate the potential for this analysis to inform better allocation decisions and to be a sound base on which to develop allocation policy and strategies. The case studies indicate that having information on the likely pattern of changes in the key variables that drive changes in underlying marginal net benefits and the ability to analyze the implications that these changes have for optimal allocation can assist fisheries managers to make better current allocation decisions.

Equally important, in each case study the process of applying the model generated valuable insights into the key drivers of change in the relative commercial and recreational values for the fishery and raised important policy issues that went well beyond the core objective of this research. This demonstrated that the process of applying the model is valuable in its own right. In this sense the model framework is a structured way to approach allocation that encourages managers to focus on their understanding of the key variables influencing optimal allocation and this is valuable in its own right.

### *Outcomes*

The outputs of this project were designed to supplement the theoretical framework and the comparative static model from the previous research[5] in a logical, consistent and stepwise way. It is important to note that the current research takes the marginal

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[4] Op cit 1

[5]Op cit 1

values of recreational and commercial fishing developed in the previous research and uses them but does not require them to be repeated. The current research requires base values for the marginal net benefit of recreational and commercial fishing but is separate from the process of setting those values. This allows the overall allocation problem to be partitioned in sensible way into (i) determination of the starting values for the marginal net benefit from recreational and commercial fishing, and (ii) analysis of changes over time in these starting values and the impact of these on optimal allocation.

Fisheries management agencies and stakeholders will benefit from using this approach. Application of the model can provide them with a reasonable starting point for developing resource allocation policy in a structured and disciplined way. The rigorous application of these methods and techniques will lead to a more informed resource allocation decision-making process. The dynamic model can provide a sound basis for thinking more strategically about stock allocation over time.

An important finding is that our knowledge of what drives changes in the marginal net benefit of recreational fishing is relatively poor. The application of the dynamic model also highlights the paucity of reliable data on the key underlying drivers of the demand schedule of recreational fishers. There would be potentially significant benefits from further economic research to better understand and quantify the key variables and drivers underlying recreational fishing demand and to better understand individual recreational fishing behaviour. This would not only enhance our ability to implement allocation policy but would also enhance our ability to manage the recreational allocation within the recreational sector.

**KEY WORDS:** **Fisheries economics; fisheries management, resource allocation; evaluation framework; socially optimal allocations**

# AN INTRODUCTORY OVERVIEW

## 1. BACKGROUND

Fisheries-related resources are finite and the need to share these resources among competing uses is inevitable. These resource sharing issues can be extremely contentious, politically difficult, and are often a significant drain on fisheries management agencies' and stakeholders' limited resources. Hence, there needs to be a consistently sound and rational basis for assessing these allocation issues that is widely understood and generally acceptable as fair and reasonable.

Socio-economic valuation tools are recognized as a key component of ecological sustainable development (ESD) assessments of our natural resources. Recent projects, including two previous FRDC-sponsored projects, describe both the appropriateness of such analyses and the need for their use.

The research in this project presents a dynamic model based on economic principles that can be used to evaluate the likely future direction of the socially optimal inter-sectoral resource allocations over time. The research illustrates the application of the model in three Western Australian case study fisheries. These case studies illustrate the nature of the data used to implement the model, the method of analyzing that data and the determination of the optimal allocation path over time using these data and relationships.

The approach and techniques are not specific to the case study fisheries. The basic model structure is general and will be applicable in any situations where a classic zero sum allocation issue arises. In this sense the combination of the model and its application to the case study fisheries provides a useful reference for managers of other fisheries, including those in other States that face similar allocation situations.

The further methodological development and empirical analysis of the case study fisheries contained in this report, adds value to the previous FRDC-sponsored research regarding sector-specific socio-economic valuation (Hundloe, *et al*) [9], and the comparative static inter-sectoral allocation model (McLeod and Nicholls) [10].

[9] Hundloe, T 'An Economic Framework for Valuing Fisheries Resource Use' (2003) A collection of papers prepared by Hundloe (and others) on how to value fisheries resources in various uses.

[10] McLeod P and Nicholls, J. 'Socio-Economic Valuation of Resource Allocation Options between Commercial and Recreational Sectors' (2004).

## 2. THE NEED

The research fulfils a substantive and practical need at a State and National level for an allocation model that can provide sound and reliable insights into the likely future direction of socially optimal allocations over time.

It does this by developing a consistent framework that integrates the key variables that cause changes in the relative value of commercial and recreational fishing over time into a dynamic model that allows the time path of the socially optimal inter-sectoral allocations to be estimated.

More specifically the need for this modelling framework is addressed by:

- developing a general theoretical analysis and associated model based on economic principles that indicate the key variables that will likely impact on the relative commercial and recreational fishing values over time and how these impact on socially optimal allocations over time. This provides a consistent and structured way for evaluating the net benefits of various resource sharing options over time;
- developing a dynamic model based on this general framework that allows the socially optimal allocation path to be estimated without the need for regular and expensive surveys of recreational and commercial fishers;
- applying this dynamic model to case study fisheries chosen to illustrate how the model can provide substantive guidance for fisheries management agencies and stakeholders in addressing inter-sectoral resource allocation; and
- providing supporting information to fisheries management agencies for use in integrated fisheries management approach to fisheries resource management with a consistent framework for socio-economic analyses in addressing resource allocation options and a sound basis for determining appropriate and relevant socio-economic criteria and benchmarks under the ESD initiative.

## 3. THE RESEARCH OBJECTIVES

The overall objective of this project was methodological and explicitly designed to supplement the theoretical framework and the comparative static model from the previous research by McLeod and Nicholls[11] in a logical, consistent and stepwise way.

In particular, the project objectives were threefold, namely:

[11] Op cit 4

- the development of a general framework that provides a theoretical basis for identifying key variables that impact on commercial and recreational values over time;

- the documentation of a robust dynamic model capturing the significant variables that impact on these values over time and how these impact on socially optimal resource allocation through time and which allow simulations of the optimal resource allocations over time; and finally,

- the calibration of the dynamic framework and model using three case study fisheries from Western Australia, that is, a metropolitan crab fishery, a metropolitan abalone fishery and a demersal 'Wetline' fishery.

The methodological framework adopted identifies the key variables that can change the relative commercial and recreational values over time and how these key drivers can impact on the socially optimal inter-sectoral resource allocation over time.

The documented model captures the key relationships that change the relative values and shape the time path of allocation adjustment over time. This provides a sound and consistent basis for evaluating the socially optimal resource allocation over time.

The key relationships in the model were calibrated for each of the case study fisheries and then used to estimate the time path and quanta of allocation adjustments for optimal allocation path in each of these fisheries. These were the same three fisheries that were used to demonstrate the application of the comparative static allocation model in the earlier research by McLeod and Nicholls.

## 4. RESEARCH METHODS

The analysis used is a logical and consistent extension of that described in previous FRDC-sponsored research on economic valuation techniques and comparative static allocation methodology and techniques.[12]

This earlier research used contingent valuation surveys of recreational fishers and revenue and cost surveys of commercial fishers to estimate the marginal net benefit functions for recreational and commercial fishing. These functions were then the basis for assessing the optimality of current allocations and determining the socially optimal allocation based on the principle of equating marginal net benefits. While this analysis provided detailed understanding of values and optimality at a point in time, it was a

[12] Op cit 3 and 4

specific objective of this study to develop a framework that did not require repeat surveys to be routinely conducted in making allocation decisions. This research focused on a model that would allow insights to be gained by fisheries managers into optimal resource allocation over time by starting with:

i) initial base values, possibly based on surveys, and

ii) reliance on non survey information on the key drivers of changes in these values.

The two components needed to be structurally separate with the key being to develop a framework that would allow the information in (ii) to be used to transform the base values/functions in (i) so that insight could be gained into the way that the relative value of commercial and recreational fishing would change over time.

An initial literature search was undertaken to identify the current state of research on developing and applying allocation frameworks and on modelling approaches and techniques. This was central to the development of the general theoretical framework and encompassed understanding the experiences elsewhere in applying various techniques for allocation policy evaluation in natural resource use.

This search did not reveal any instances of inter-temporal allocation modelling of the kind proposed for the current study. Quite the contrary in fact with the bulk of allocation analysis concentrating on finding optimal shares that could be kept in place over time. As the general framework presented below in Part 1 shows this is unlikely to be an optimal strategy.

The lack of instances of inter-temporal allocation analysis in fisheries and the desire for a straightforward framework meant looking elsewhere in resource management. The model developed is based on the concept of modelling the growth over time in marginal net benefits (shifts in net benefit functions) and has its roots in early work by Krutilla and Fisher which has since been modified to deal with a number of land planning issues that involve allocating land between competing uses. [13]

The study was designed to demonstrate the application of the model produced. For this purpose, the results from the comparative static modelling for each of the three case study fisheries that were contained in the earlier research by McLeod and

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[13] Fisher, A.C. & J.V. Krutilla, 1975, Resource Conservation, Environmental Preservation, and the Rate of Discount, *Quarterly Journal of Economics*, August, 358-370.

Nicholls were taken as the benchmark data and the respective start values for the application of the dynamic model. In order to fulfill the requirement of applicability by fisheries managers, the dynamic framework was developed in a way that allows calibration using published data available on the key variables in the model.[14]

## 5. THE RESEARCH OUTCOMES[15]

### *5.1 The Framework Principles*

In economic theory, the socially optimal allocation of a defined total sustainable catch is where the marginal net benefits to society from commercial and recreational use are equal. There is no other allocation within that total sustainable catch where the net benefits from combined use will be greater. These relevant values and how they can be identified and measured were explained in earlier research[16].

These principles do not change when we move the allocation decision into a dynamic framework but they then need to be applied over time. The key to doing this is to understand that the marginal net benefits schedules will change (shift) over time. This is shown in Figure 1 below.

These shifts necessitate re-establishing the equality between the marginal net benefits for competing uses by making appropriate adjustments to the inter-sectoral allocation. The illustration in Figure 1 shows a case where the changes are such as to shift the optimal allocation in favour of commercial fishing over time.

The research in this project describes what key variables can change these relative values over  time and how these drivers can be measured and then applied to identify the optimal inter-sectoral allocation path of the fish stocks over time. The basic model is documented in Part One, the General Theoretical Framework.

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[14] This is not to say that original data collection will never be needed. Situations will arise where the required data is not readily available, (e.g. income elasticity of demand for recreational fishing) and then a decision will be needed as to whether original analysis is needed or whether appropriate approximations based on available measure are justified.

[15] As this methodological research is designed to provide a better understanding among non-economists involved in fisheries management it has meant a degree of sacrifice of economic precession in favour of a practical presentation of the general theoretical framework and its application to the three case study fisheries.

[16] Op cit 4

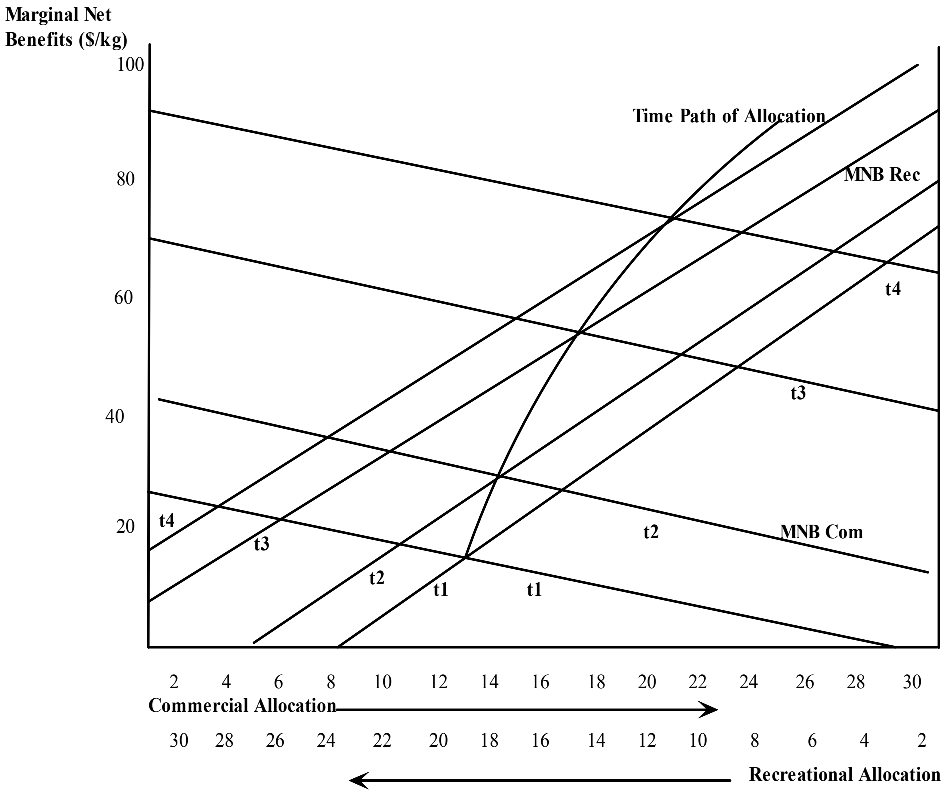


**Figure 1: Shifts in Optimal Allocation of Given Stock Between Recreation and Commercial Fishing Over Time.**

The theoretical model was built on the relationships that lie behind the marginal net benefit schedules for commercial and recreational fishing. There were two parts to this. First, a framework for each marginal net benefit schedule that identifies the key variables that cause shifts and analyses the way that these key drivers influence changes in marginal net benefits. This is a method for quantifying the sort of shifts over time that are illustrated in Figure 1. Second, a relatively straightforward model is specified for calibrating the key relationships that shape the time path of allocation adjustment over time.

The first part fits neatly within the conventional demand and supply framework and its application to commercial and recreational activities outlined in previous research[17] . It is based on the idea that there are demands for recreational and commercial fishing activities and associated supply responses. It recognizes that the balance between these demands and supplies influences the net benefit associated with these activities and changes in these underlying demand and supply schedules generate shifts in the net benefit schedules. The second part fits well with those

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[17] Op cit 4

models in economics which focus on relative growth rates for net benefits as part of benefit cost analysis of policy evaluation.

The dynamic model is not designed to specify optimal solutions in terms of exact timing and quanta of future stock re-allocations. Rather the model provides helpful insights into the likely future direction of the socially optimal allocations over time for fisheries managers and stakeholder when making stock allocation decisions today.

The theoretical model is based on the notion of a defined total allowable catch that will be in existence overtime and which is to be allocated optimally between commercial and recreational sectors in a zero sum game.

### *5.2 The Case Study Outcomes*

For the purposes of applying the dynamic model, certain key conditions (e.g. defined total allowable catches, binding constraints on both sectors and optimal intra-sectoral behavior and allocations) were assumed to be met.

In all three case studies, the results from the application of the comparative static model in the earlier research by McLeod and Nicholls were taken as benchmark information for the dynamic modelling. For the quantification of the key variables that drive changes in relative recreational and commercial values, we did not engage in original data collection and analysis but relied on publicly available data supplemented by direct information from participants ( for example on expected aquaculture investment).

The outcomes from all three case studies showed that the theoretical framework can be usefully applied. The results in all three fisheries provided:

- meaningful insights in to direction, extent and timing of inter-sectoral stock re-allocations in the future if socially optimal allocations were to be achieved and maintained over a five year period; and
- a sound base on which to develop allocation policy and strategies.

In this way, the results from dynamic resource allocation modelling allow structured thinking about the best course of allocation adjustments over time. This enables the adoption of a more strategic approach to the development of allocation policy in a fishery.

Summary results on allocation for each of the case study fisheries are shown below in Figure 2, Figure 3 and Figure 4.

They show the nature of the shift in allocation needed in each fishery to maintain an optimal allocation over time. In each case the initial change to achieve optimality is the largest with more modest changes subsequently. The diagrams highlight that an important consideration is whether stock re-allocations in the future are likely to be asymmetric or not.

With the sort of knowledge contained in these diagrams giving indications of both the scale and timing of the allocation adjustments needed in the future, the pattern of adjustments can be planned to achieve the best outcomes over the short to medium term (i.e. 5 to 8 years). This can be done making due allowance for adjustment and transaction costs.

In two of the three case studies (Abalone and Cockburn Sound Crab) the dynamic modelling results reinforced the direction of the indicated initial re-allocation required based on comparative static modelling and the required re-allocations were likely to be uni-directional over the next five year period. For the other case study ('Wetline' fishery), the dynamic modelling results showed that the initial re-allocation to the commercial sector indicated by the comparative static modelling would be progressively reversed over the next 5 to 7 years.

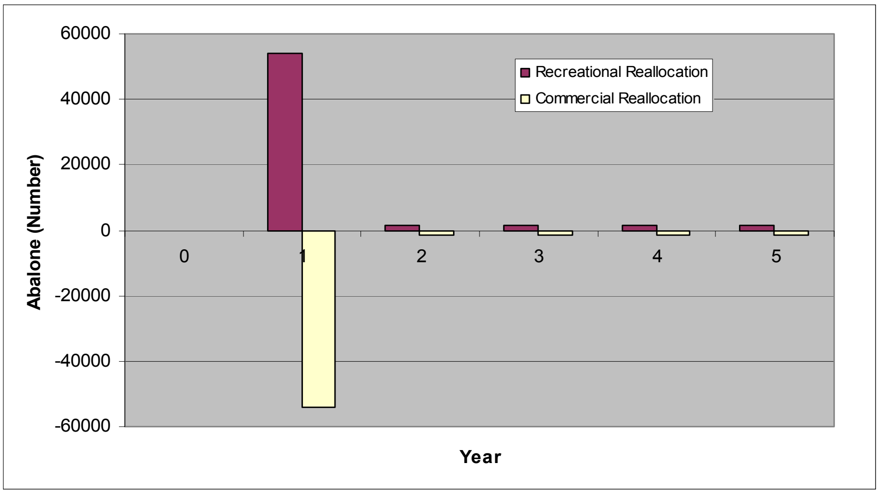


**Figure 2: Time Path of Adjustment for Abalone**

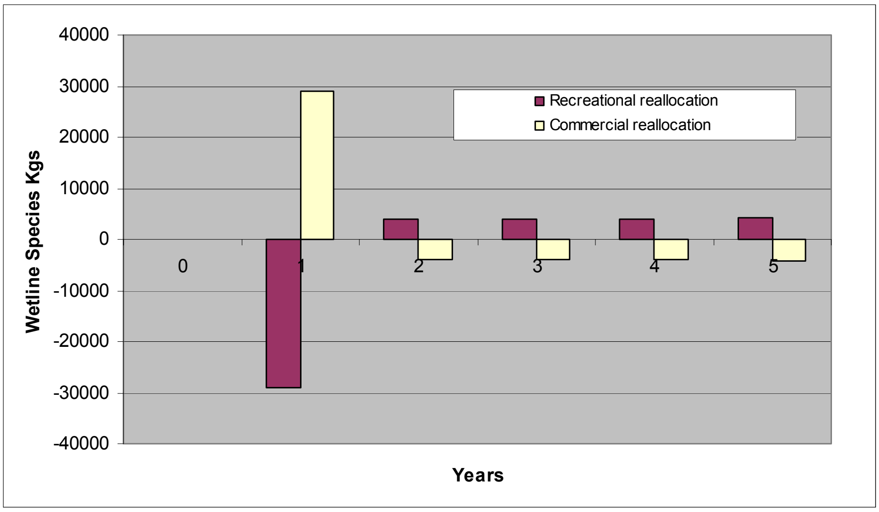


**Figure 3: Time Path of Adjustment for Wetline Species**

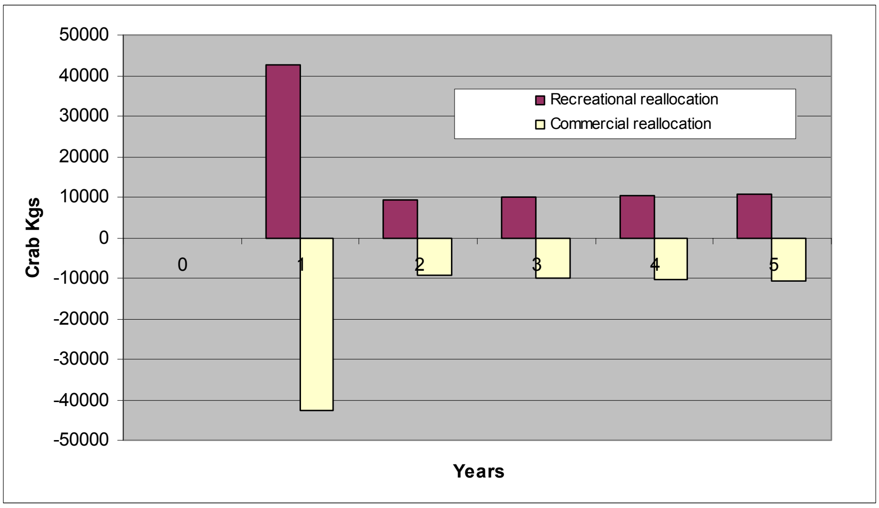


**Figure 4: Time Path of Adjustment for Cockburn Sound Crab**

## 6. BENEFITS AND ADOPTION

The results from this research provide fisheries managers and other stakeholders with a set of theoretical and practical materials that enable a structured and disciplined approach to formulating allocation policy based on economic principles of natural resource management. They enable the identification of appropriate methods for evaluating and planning the allocation of fish resources over time between competing uses.

In the case of the current research report, the specific results highlight the decision value for managers of having an insight into future stock allocation requirements. In the case where the subsequent allocation changes are expected to reinforce the initial change, the results put the fishery manager is a position to make a decision on the total adjustment needed and can frame a path to achieve the result over time. Rather than have a large shift followed by a series of smaller shifts, it may be preferable to spread the change out more evenly over the period. In the case where reversal of any initial allocation adjustment is indicated in future periods, the results enable the an assessment as to whether the initial change should be made at all, especially if significant transaction costs are present or likely in making current and future adjustments.

The dynamic model as developed is also capable of sensitivity analysis. This enables fishery managers (and stakeholders) to gauge what happens to the direction, scale and timing of stock re-allocations over time under different growth factors for commercial and recreational sectors or under different values for particular key variables that impact on these growth factor values.

In addition to the above, and equally important, because it is a structured process, in each case study the process of identifying and collecting the relevant data and applying the model generated valuable insights into the management of allocation in the fishery and raised important policy issues that went well beyond the core objective of the project. This demonstrated that the process of applying the model is valuable in its own right, not just the final allocation results.

The benefits of the research are expected to increase over time through extension. As with most economic policy analysis with respect to natural resource management, the benefits arise from the extension of the principles to inform policy making. Actual implementation of the model as presented will vary from case to case.

As part of the project, case study seminars were held in all States which allowed fisheries managers and representatives of commercial and recreational sectors to participate "hands on" in cases designed around assessing base values (marginal net benefits) for a sample of local fisheries.

Seminars illustrating the use of the model have also been held at the Western Australian Department of Fisheries. The Integrated Fisheries Allocation Advisory Committee in Western Australia requested a presentation of the model and the abalone case study results so that they could take the model and its results into account in determining the policy for the allocation of abalone in Western Australia. Seminars were also held for the Western Australian Fishing Industry Council.

Managers from the New Zealand Ministry of Fisheries attended a presentation of the model and results at the "Share the Fish 06" Conference in Fremantle and subsequently requested the full documentation to consider what lessons they could learn for application to their own fisheries. With approval from FRDC they were sent a copy of the complete final draft report.

Fisheries stakeholders around Australia would benefit from further extension based on applying the full dynamic assessment to the material from the previous case study seminars.

## 7. FURTHER RESEARCH DEVELOPMENT

Given the primary focus of this research is methodological, further research would be necessary for the framework to be used to inform actual resource allocation decision making processes in the case study fisheries. In particular, some of the data deficiencies identified would need to be addressed to allow better estimates of the key variables that drive changes in the relative commercial and recreational values.

There are two aspects to these data issues. On the commercial side, greater understanding is needed in some basic areas, such as the price elasticity of demand for fish and the degree of substitutability between local wild stock, imported and aquaculture product.

On the recreation side, we found the economic literature to be lacking information that could assist in the quantification of key characteristics of recreational fishing demand. For instance, the application of the dynamic model would benefit greatly if there were methodologically sound estimates of the sensitivity of recreational fishing demand in various fisheries to changes in income and of changes in participation rate with age and over changes in the stage of the family life cycle.

An important lesson arising from this research is that the current level of understanding of recreational fishing behaviour is not as well developed as it could be for the application of the evaluation framework and dynamic allocation modeling. It is less than will be required in future for effective management of allocation policy and processes and less than will be required for effective management of the actual allocation to fishers where achieving optimal intra-sectoral sharing outcomes and optimal monitoring and compliance outcomes will become a growing policy issue.

There is also a need for a better understanding of the biomass as it pertains to the effort of recreational and commercial fishers. Under reallocation, to achieve higher catches recreational fishers will have to increase fishing effort or wait a period for the reduced commercial catch to impact biomass. For some fisheries where commercial and recreational activities are spatially separate allocation policy based on the dynamic model will need improved information on whether the biomass they are fishing is the same biomass and whether recreational fishers can relocate their effort spatially to take account of the reduced commercial allocation.

Given that the sort of evaluation framework proposed in this and the earlier research is not currently applied in resource allocation decision making processes, adoption may also be aided by a suitably structured and well targeted training program on the dynamic resource allocation modelling for managers, fisheries agencies and representatives of commercial and recreational fishing support organisations.

The adoption of this framework will be accompanied by a demand for particular socio-economic data sets that are not currently collected and made available on a routine basis. How any such emerging data demands might be best satisfied in a cost effective way may warrant joint State and National consideration, possibly in the context of the FRDC-sponsored ESD project.

## 8. PLANNED OUTCOMES

As set out in the original planned outcomes, the actual outcomes from this research (model and case study results) have proved to be consistent with allowing fisheries managers to take a planned strategic approach to resource allocation. The adoption of the final project outputs will assist resource allocation decision making by identifying socially optimal resource allocations through time.

The original planned outcomes highlighted the need for a forward-looking allocation policy.  Again the results indicate the importance of being able to think ahead. Within the results (model and case studies) is the case that some fisheries require unidirectional changes in allocation going forward while others require changes in the direction in the sense that what appears to be the optimal allocation today is not the optimal allocation tomorrow and a change in allocation today may have to be partially or fully reversed in future.

The results indicate that application of the model will enable fisheries management to make better informed decisions today because they will be a position to consider the likely pattern of future socially optimal allocations based on a systematic analysis of trends in key socio economic variables that drive changes in underlying commercial and recreational use values.

By focusing on socially optimal allocations through time, the risks of erroneous or sub optimal short term allocation changes that could require reversal in the future can be minimized. Where the model indicates a unidirectional change in allocation in future years and quantifies it, the overall change can be planned such that the resource and social costs of adjustment are minimized.

Overall the model and results have proved consistent with the original planned outcome to develop a framework consistent with managing allocation within an ESD framework.

## 9. CONCLUSIONS

This research has applied a general theoretical framework for evaluating inter-sectoral resource allocation options to three test fisheries. The results show that the dynamic model can be usefully applied and can produce useful insights on the likely direction, scale and timing of stock re-allocation over time if socially optimal allocations are to be achieved and maintained. Moreover these are insights that are not available from static analysis of values and they indicate that the focus on determining shares as a way to deal with allocation is unlikely to be an optimal strategy.

These results should provide all interested parties with greater insights for developing resource allocation policy and strategies. They should also lead to more informed resource allocation decision-making processes.

The outcomes of this research combined with those from the comparative static modelling from the earlier research by McLeod and Nicholls provide fishery policy makers and stakeholders with a comprehensive set of 'tested' methodological tools that, if applied rigorously, can provide an economically sound and rational basis on which to develop allocation policies and strategies in a fishery.

ERA
ECONOMIC RESEARCH ASSOCIATES

# DYNAMIC MODELLING OF THE SOCIALLY OPTIMAL ALLOCATION OF FISH RESOURCES BETWEEN COMMERCIAL AND RECREATIONAL USE

**(FRDC Project 2003/039)**

# PART ONE

# A GENERAL THEORETICAL FRAMEWORK

**By R Lindner, P McLeod and J Nicholls**

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# 1 Introduction

## 1.1 Background

Fisheries-related resources are finite, and the need to share these resources between competing users is inevitable. This often involves decisions about which fish consumers should be allocated the sustainable take (i.e. those consumers, domestic or elsewhere, who want to buy their fish at retail outlets, including restaurants, or those who want to catch their own as recreational fishers). Others can relate to marine resources set aside for passive uses (such as 'no take' areas in the form of marine parks or fish and fish habitat protection areas for those who want to view a pristine marine environment or derive increased satisfaction in the believe that fish stock are locked up for the enjoyment of current and future generations and those who may simply want to enjoy the fishing experience in the form of catch and release).

These resource-sharing issues can be extremely contentious, and often are politically difficult. As a result, they can be a significant drain on fisheries management and stakeholders' resources. Hence, there is a clear need to develop a consistent rational basis for determining these allocation issues that is widely understood and generally accepted as fair and reasonable.

In relation to sharing the sustainable take, significant progress toward meeting this need has been made due to FRDC supported research by Hundloe[1] et. al., and a subsequent FRDC funded project (2001/065) by McLeod and Nicholls[2]. The later research has provided fisheries management with tools to estimate the marginal value of fish caught by the commercial and recreational fishing sectors.

As a result, fishery managers now have access to a clear explanation of the appropriate conceptual framework for resource allocation decisions and to sound and consistent guidelines for applying suitable economic tools to estimate values that enable making 'like-with-like' comparisons between competing resource uses. This established benefit-cost framework now has been applied to three case studies in project 2001/065 to demonstrate how to use the framework and valuation

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[1] Hundloe, T, 'An Economic Framework for Valuing Fisheries Resource Use, Draft for Consideration' (undated). A collection of economic papers prepared by Hundloe (and others) for an FRDC project on how to value fisheries resources in various uses.

[2] McLeod ,P and Nicholls,J. 'Socio-Economic Valuation of Resource Allocation Options between Commercial and Recreational Sectors' (2004).

methodologies for evaluating resource allocation options and determining the optimum allocation of a fish resource stock.

Knowledge derived from applying this approach can be used to benchmark an existing inter-sectoral allocation for a given fishery at that point in time, and to help inform decisions about the direction of resource stocks reallocation at that point in time to optimize economic and community benefits. The official communiqué from the Coolangatta Recreational Fishing Rights Workshop[3] formally recognized and endorsed the application of the framework and tools developed in this project for evaluating resource allocation options and measuring socially optimum allocations in Commonwealth fisheries.

However, resource allocation decisions based on a static benefit-cost model identified by project (2001/065) reflect the assessment of appropriate resource allocations at a particular point in time. Whilst it is critical to identify socially optimal allocations at a given point in time, it is equally important to recognize that this solution is likely to change over time.

As the economic and social climate changes over time, the associated commercial and recreational values and the socially optimal allocation will also change. For example, changes in individual incomes and population will affect seafood demand and, consequently, commercial use values over time. Recreational fishing participation rates will change over time, due partly to an aging Australian population and declining youth participation in recreational fishing. These changes will impact on future recreational fishing demand, and on consequential recreational values. Changes in these (and other) variables that influence the underlying relative values of commercial and recreational fishing will change the socially optimal location through time.

Hence, the results from static benefit-cost analyses of inter-sectoral fish stock allocations that employ these methods need to be updated regularly. As contemporary social and economic values change over time, at least partly in a predictable manner, it is important to understand trends in the key drivers of the relative values of commercial and recreational fishing. As defined by the established conceptual framework developed in the above studies, the static analysis of the optimal allocation of a fish stock among competing users could have a short shelf life if the underlying conditions are changing markedly.

[3] The Coolangatta Workshop Communique, The Principles and Strategies to underpin the development of Recreational Fishing Rights and Resource Allocation in Commonwealth Fisheries, October 2002.

The insights gained from their existing research led McLeod and Nicholls[4] to highlight that the determinants of fish stock values are likely to change over time as the underlying determinants of values change. However, whilst fisheries management have a well defined framework and tested tools for comparative statics, decision makers have now recognised that a supplemented framework and tested tools that are capable of modelling the impact of changes in key drivers on commercial and recreational relative values over time, and on consequential changes in the socially optimum allocation through time would be worthwhile. Consequently, fisheries management could then be more confident that current inter-sectoral resource allocation decisions are consistent with likely longer-term socially optimal outcomes.

In looking for a framework and set of tools to evaluate resource allocation options and to measure optimal allocation for the purposes of satisfying legislative, including ESD, objectives, decision makers may need to be able to resort to:

- a more general dynamic framework to look at optimal resource allocation through time;
- a socio-economic analytical framework with a consistent methodology and additional set of tested tools that explicitly take into account variables impacting on the optimization of socio-economic benefits from commercial and recreational uses through time;
- practical guidance in the application of the dynamic framework and advanced methodologies to address inter-sectoral related resource-sharing issues over time; and
- additional supporting methods and tools for a consistent framework for socio-economic analysis of inter-sectoral resource allocation options over time that Australian fisheries agencies can use in the development of an integrated coastal fisheries management initiative.

Such supporting methodologies and tools will enable fisheries management throughout Australia to develop future inter-sectoral allocation strategies within integrated fisheries management initiatives

## 1.2 Project Objectives

The objective of this project is to develop a dynamic benefit-cost model to assist with resource allocation decisions for fisheries. Specifically,

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[4] Op cit 2

- the development of a general framework that provides a theoretical basis for identifying key variables that impact on commercial and recreational values over time;
- the documentation of a robust dynamic model capturing the significant variables that impact on these values over time and how these impact on socially optimum resource allocation through time and which allow simulations of the optimal resource allocations over time; and
- the demonstration of the application of the dynamic framework and modelling tool through three case studies associated with the previous FRDC supported socio-economic valuation project (2001/065). This advances the outputs from project 2001/065 in a logical, consistent and stepwise way.

## 1.3 Project Outputs

The intended outputs of the project include:

- a general and consistent theoretical framework of commercial and recreational values over time that incorporates key drivers of changes in the marginal net benefits of commercial and recreational fishing;
- a robust dynamic model to help inform decisions about the optimal inter-sectoral resource allocation through time that takes account of changes in variables impacting on the relative benefits of both commercial and recreational use over time; and
- practical guidance to fisheries management based on the application of the above theoretical framework and the dynamic model to three case studies; namely the Cockburn Sound crab fishery, the West Coast ‘wetline’ fishery and the Perth abalone fishery.

# 2 Basic Dynamics

## 2.1 Comparative Statics

The widely accepted conceptual framework on which to base resource allocation decisions is based on the well established principle that total net economic benefit from a resource stock is maximised when it is allocated between the commercial and recreational sectors so that the marginal net economic benefits for the competing uses are equal. This was the basis of the static benefit-cost model employed in project 2001/065 to evaluate alternative allocation options, and is useful as an aid to determine the optimal allocation at a point in time.

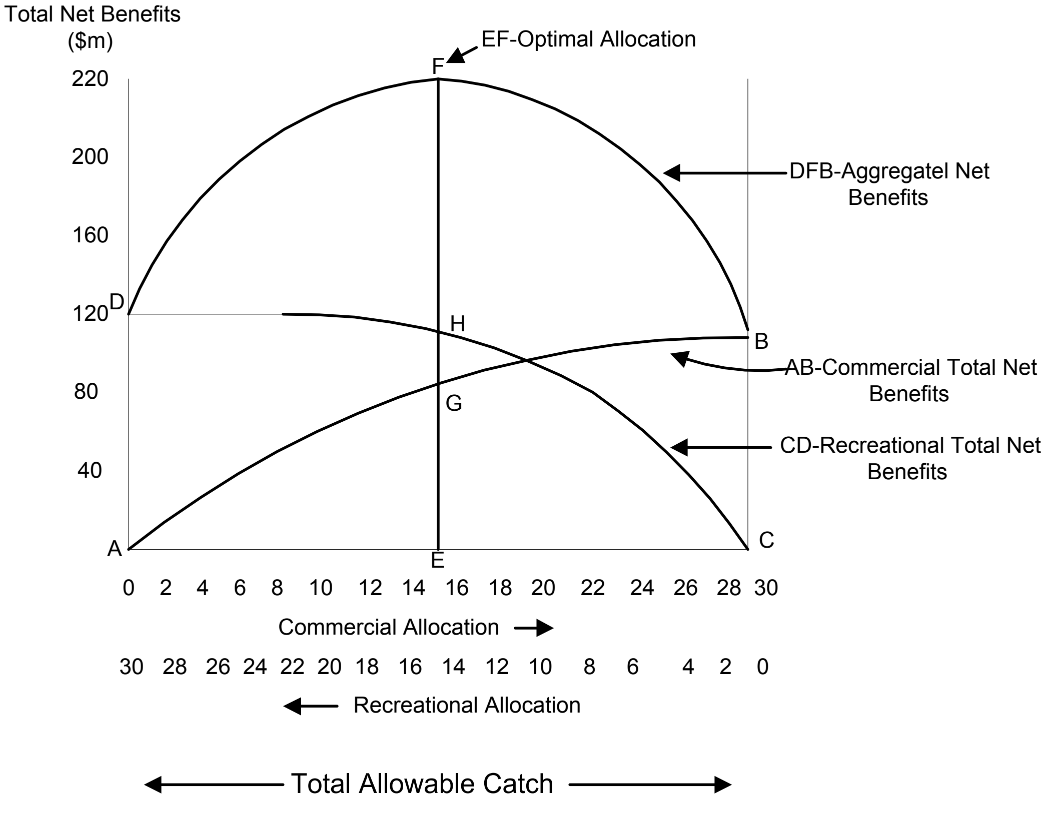



**Figure 1: Aggregate Net Benefits of Resource Stock Allocation**[5]

[5] A detailed explanation of the structure of these aggregate benefit curves for commercial and recreational fishing can be found in Edwards, Steven F 'An Economic Guide to Allocation of Fish Stocks between commercial and Recreational Use' (November 1990) NOAA Technical Paper NMFS 94, and in the research by McLeod and Nicholls, *op cit 2*.

Figure 1 above reproduces aggregate net benefits derived by each sector from different allocations of the resource stock that is an essential feature of this model, and illustrates the relationship between them. The left vertical axis records total net economic benefit (in $ terms) for the commercial fishing sector (curve AB), the recreational fishing sector (curve CD) and the two sectors combined benefits (curve DFB). In this figure, the length of the horizontal axis represents total allowable catch (expressed in quantity terms). Reading from left to right, the horizontal axis measures increasing allocation of a fixed level of sustainable catch to the commercial fishing sector. Conversely, reading from right to left, the horizontal axis measures increasing allocation of a fixed level of sustainable catch to the recreational fishing sector. A critical assumption underlying this approach is that the size of the fish stock, and/or the sustainable total allowable catch is known.

In this theoretical model, the optimal allocation is at the apex of the combined total net benefit curve DFB because there is no other allocation that produces a greater combined net benefit. This is denoted by point F that represents a stock allocation of 16 units to the commercial sector and around 14 units to the recreational sector with total net benefits to each corresponding to points G and H respectively.

There may be increased benefits to a particular sector from a greater allocation beyond the optimal allocation. For instance, increasing the allocated share of the fish stock to the commercial sector by shifting the allocation to the right of point G in Figure 1 above. However, the gain in aggregate net benefits to the commercial sector is outweighed by the loss of recreational benefits in re-allocating catch away from the recreational to the commercial sector and thus the combined total net benefits falls.

This phenomenon is explained by the concept of marginal net benefits (expressed in $ per unit quantity) that is illustrated in Figure 2 below. The marginal net benefit schedules for each sector are derived from the total net benefits curve for that sector. The schedules measure from the total net benefit schedule the unit value that explains the change in total net benefits for each additional allocated unit of stock. The area under each of the marginal benefit schedules measure the aggregate net benefits derived by each sector from each additional allocated unit within the sustainable take. The downward sloping nature of the both marginal benefit schedules typically reflects the concept of diminishing values for each sector as the catch allocations increase.

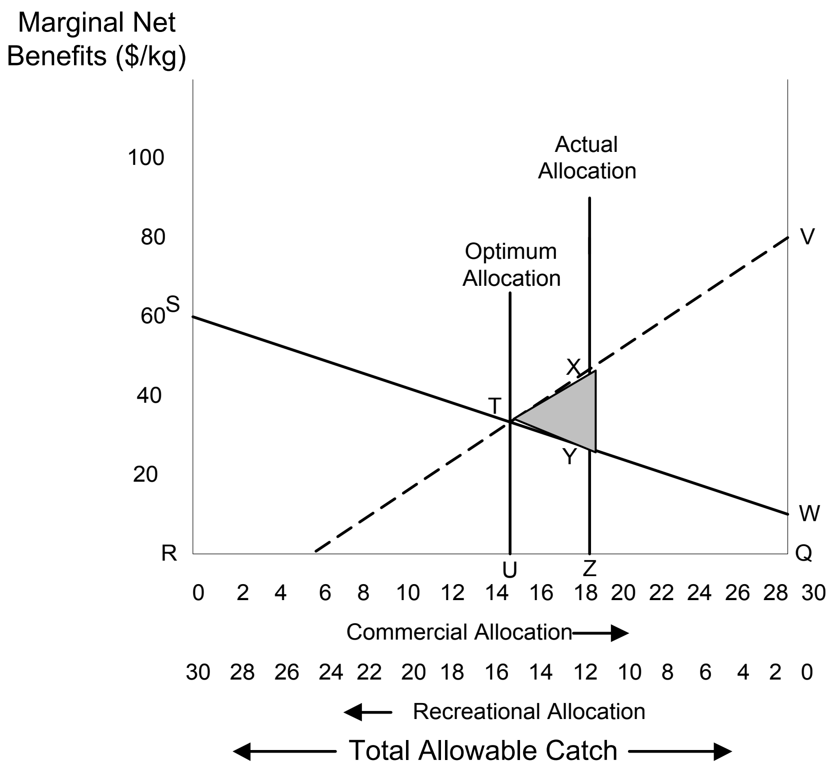



**Figure 2: Marginal Net Benefits of Resource Stock Allocation**

Reading from left to right, the marginal benefit from commercial use as the allocation increases from zero to 30 units. Conversely, reading from right to left is the marginal benefits from recreational fishing as the allocated share increases from zero to 30 units. Figure 2 shows that the marginal benefit of increasing the allocated catch to the commercial sector from zero to 2 units greatly exceeds the marginal benefits that recreational fishers derived from a catch allocation increased from 28 units to 30 units. Therefore, there are increased aggregate benefits by re-allocating this catch to the commercial sector away from the recreational sector. As shown in Figure 2 this is true up until 16 units.

Conversely, the marginal benefit of first unit caught by the recreational fishers is usually high and in the theoretical example given in Figure 2 above exceeds the marginal benefit of those fish in commercial use. Consequently, there are increased aggregate benefits by re-allocating catch away from the commercial sector to the recreational fishing up to the fourteenth unit. Significantly, at that point, and where the two marginal benefit schedules intersect in Figure 2, the marginal benefits derived by the commercial and recreational sectors are the same. This is also the case at points G and H on the optimal allocation in Figure 1 above.

Figure 2 also demonstrates the economic consequence of living with sub-optimal allocations. For instance, if more stock was allocated to the commercial fishing sector, and less to the recreational fishing sector, as depicted by the line labelled 'Actual Allocation', then combined aggregate net benefit would equal area RSYZ plus area QVXZ. The difference, equal to the area TXY, is the loss of potential aggregate net benefit from misallocation of the stock.

## 2.2 The Nature of the Dynamic Problem

This static model is useful in benchmarking relevant values for the commercial and recreational sectors for resource stock allocations existing at a point in time and for determining whether those allocations are optimal or not at that time. However, the model can be of limited use in determining the long-term optimal inter-sectoral allocation of the fish resource stock when making decisions about resource re-allocations.

Sooner or later, either or both of the marginal net benefit schedules for commercial fishing, and for recreational fishing, will shift. Hence, the theoretically optimal inter-sectoral allocation can change over time. Thus, in making any decision about resource re-allocation today, it is important to know where the optimal solution might be tomorrow.

The nature of the problem of dynamic optimal stock allocation is illustrated by depicting what can happen when the marginal net benefit schedules for either or both commercial and recreational use of a fishery change at three points in time (t1, t2, and t3, where t1 is the static model outcomes for this illustrative purpose).

### 2.2.1 Changing Recreational Values

Over time, the marginal net benefit schedule for recreational fishing depicted in Figure 3 shifts to the left (i.e. increases or shifts outwards in the marginal net benefit for recreational fishing, which is measured relative to the origin at the right hand end of the horizontal axis in Figure 3). For simplicity, the marginal net benefit schedule for commercial fishing is assumed to remain fixed, although there is no necessary reasons for it do so.

**Changing Recreational Values**

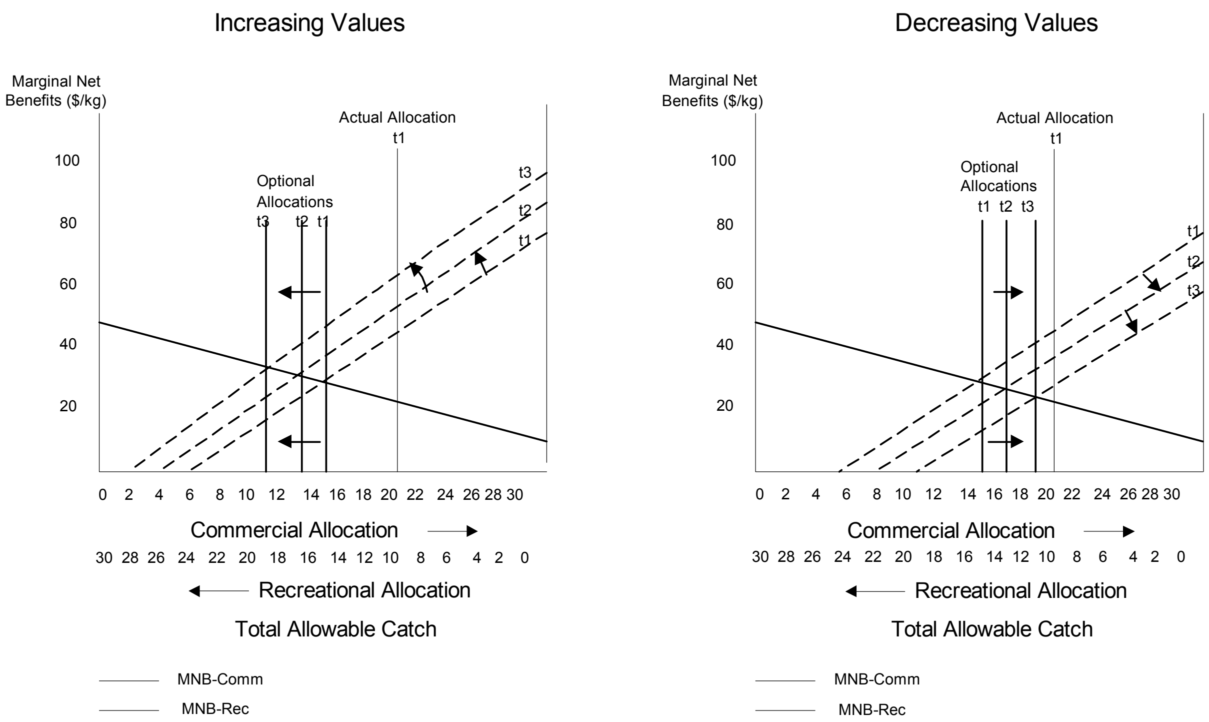



**Figure 3: Increasing Recreational Values**

**Figure 4: Decreasing Recreational Values**

Assuming that there is no corresponding change over time in the size of the aggregate sustainable annual catch, the optimal level of total sustainable annual catch to allocate to recreational fishing will increase, while the optimal allocation of sustainable annual catch to commercial fishing will decrease. This is illustrated in Figure 3, where the optimal stock allocation (i.e. that equates marginal net benefit in each sector) at time t1 involves a commercial allocation of 14 units, and a recreational catch of 16 units. Likewise, the optimal recreational allocation at times t2, and t3 will increase. If t1 were taken to be the optimal allocation identified by the application of the static model, then a fisheries management decision to re-allocate stock to the recreational sector can be taken in confidence that the re-allocation is heading in a direction that is consistent with longer term optimal allocation.

Conversely, if the marginal net benefit schedule for recreational fishing shifts to the right (i.e. decreases or shift inwards) at time t2 and t3 as depicted in Figure 4, then any decision to significantly re-allocate stock away from the commercial sector to the recreational sector based solely on a t1 snap shot of the optimal solution is not heading allocations in a direction that is consistent with longer-term optimal resource allocation in this illustrative example.

### 2.2.2 Changing Commercial Values

Similarly, if, over time, the marginal net benefit schedule for the commercial sector shifts to the right (i.e. increases or shifts outwards) over time as depicted in Figure 5, then also any significant re-allocation away from the commercial sector based on a t1 optimal solution is not be consistent with longer term optimal resource allocation. (For simplicity, in this illustration and in Figure 6, it is assumed that the marginal benefit schedule for the recreational sector remained fixed over t1, t2 and t3 and that there is no corresponding change to the size of the total sustainable catch to be shared.)

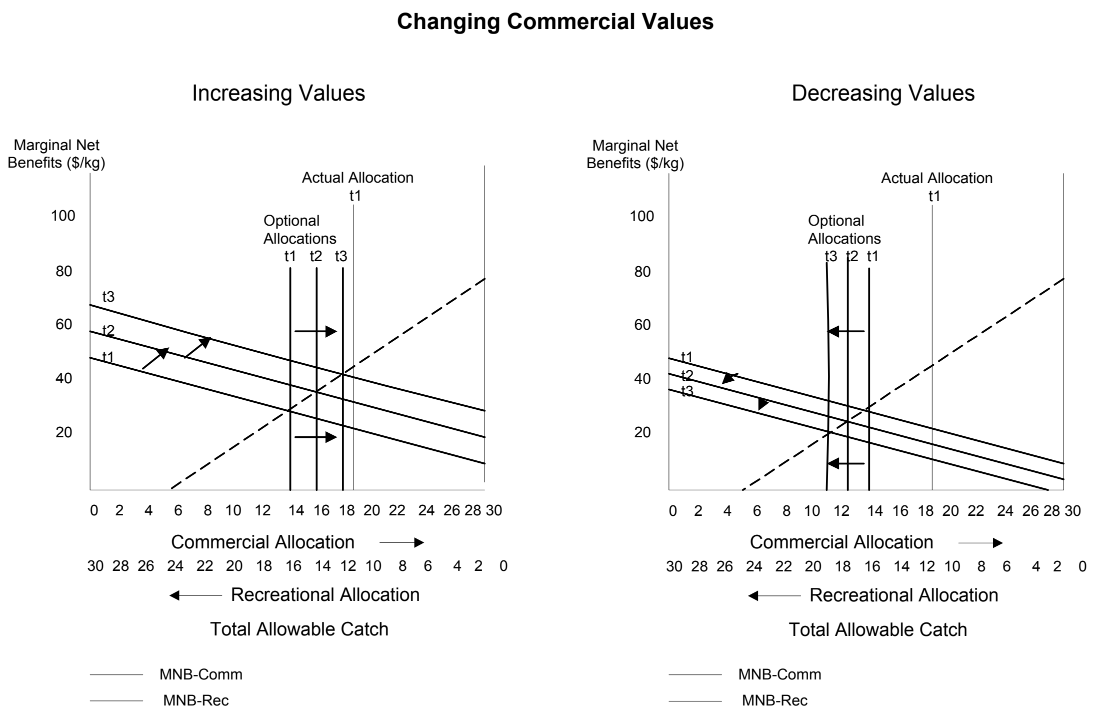



**Figure 5: Increasing Commercial Values**

**Figure 6: Decreasing Commercial Values**

On the other hand, any shift to the left (decrease or shift inwards) in the marginal net benefit schedule for commercial fishing as shown in Figure 6, then fisheries management can be confident that a decision based on a t1 solution to nudge resource re-allocation towards recreational fishing would be consistent with longer term optimal resource allocation.

## 2.3 Demand and Supply Analysis of the Marginal Net Benefit Drivers For Commercial and Recreational Fishing

In this section we consider, from a general perspective, the way that demand and supply analysis can be used to understand the interaction between key variables on both sides of the allocation issue and the symmetry that exists between the key variables on either side. Understanding these interactions will drive the formation of both the commercial and recreational side of the dynamic analysis and the data required to implement it.

In order to understand these interactions it is helpful to first consider the underlying demand and supply side drivers without the complexity of an imposed management regime (eg catch quotas, bag limits) that binds the behavior of commercial and recreational fishers. This lays the groundwork for a clearer interpretation of the way that the basic demand and supply factors are likely to change the marginal net benefits over time and the way that the existence of actual management regimes can influence this outcome.

The drivers of the marginal net benefits from commercial and recreational fishing can be found in the key variables that determine the net benefits on either side of the allocation issue. These fall under two broad groupings.

First, there are the net benefits attributable to the demand for fish by local 'retail' consumers on the commercial side and those of recreational fishers on the other. This is reflected in the willingness-to-pay, and, whilst this is observable in the commercial sector, an underlying willingness-to-pay exists in recreational fishing behaviour[6].

Secondly, there are those benefits attributable to production in satisfying the demands of retail consumers and, indeed, those of recreational fishers. The production-attributed benefits tend to be more readily associated with the commercial harvesting, processing, distribution and retailing in satisfying 'retail' consumer demand for fish. They also exist, at least in theory, on the recreational side, although they are generally much less obvious and much more difficult to specify given individual recreational fishers supply the time and other inputs in order to consume a recreational fishing experience. However, in some instance, recreational fisher may prefer to engage the services of a charter boat operator that can supply the platform, the appropriate fishing

[6] See Hundloe et al op cit 1 and McLeod and Nicholls op cit 2 for further discussion on valuing non-market goods.

gear, fuel, bait, the local fishing knowledge and time for a recreational fishing activity. In these instances, the net benefits attributable to service provision (production) on the recreational side can be more readily identified and measured.

Together, these two elements of the benefits (i.e. those attributable to consumption and those attributable to production) on either side make up the aggregate benefits from commercial and recreational fishing. Of particular interest are those variables that drive the net benefits attributable to domestic consumption (consumer surpluses) and the net benefits attributable to production (producer surpluses) at the margin.

### 2.3.1 The Primary Drivers

The primary drivers can be analysed in the context of supply and demand. As illustrated in Figure 11 below, there will be an underlying demand schedule, Dt, and, an underlying supply schedule, St, for a range of catch volumes of a fish species taken from a fishery regardless of whether constraints apply in the fishery. And this conceptual framework exists for both commercial and recreational fishing. The key is to identify the characteristics of the underlying supply and demand schedules for the fish taken from a fishery by both the commercial and recreational sectors.

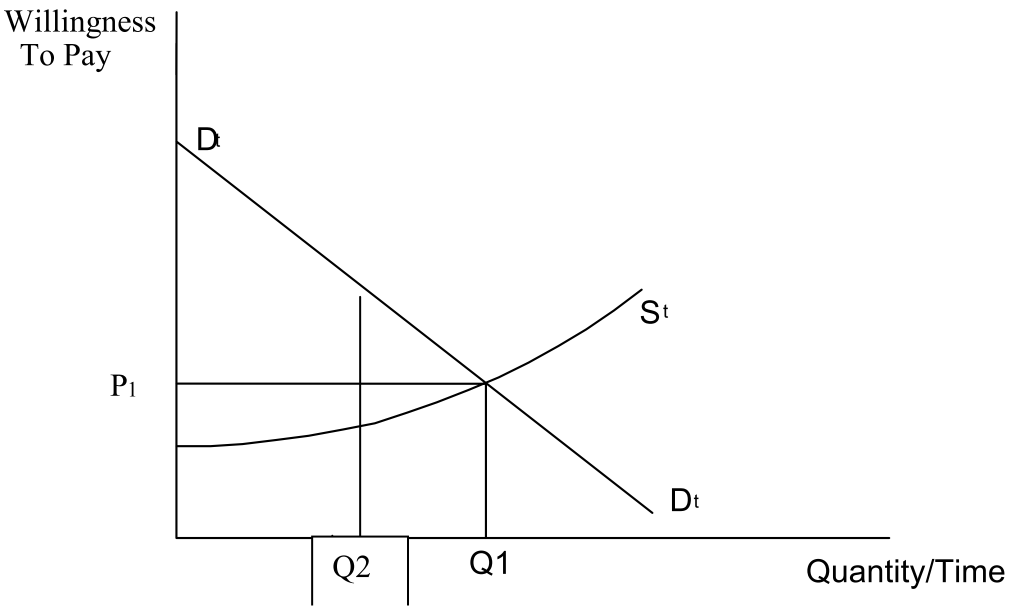



**Figure 7: Hypothetical Demand and Supply Schedules for a Fish Species**

Figure 7 illustrates that, in the absence of an imposed management regime , local ‘retail’ consumers or recreational fishers would prefer to be at quantity Q1. If the sustainable catch level were to the right of, or greater than, Q1 then there would be no need for restrictions to apply because catches are kept within sustainable levels by non-regulatory factors.

In the presence of catch and/or input controls on commercial and recreational fishing an important consideration is whether these restrictions are binding. If they are binding, then they restrict commercial and/or recreational take to fall to the left of the unconstrained equilibrium, Q1 at point like Q2. If the catch limits are not binding, then the commercial and recreational catch will be to the right of Q2, at the equilibrium Q1. In this case no allocation issue but there may be a sustainability issue if the combined catch by both sectors exceeds sustainable levels. The West Coast ‘Wetline’ fishery case study contained in previous research by McLeod and Nicholls would have been, until recently, an example of such a fishery. The bag limit constraints applying to recreational fisher and the limit on the number of commercial fishing boats with a ‘wetline’ entitlement were not constraining ‘wetline’ catch in the fishery by either sector.

In dealing with resource allocation against a background, where the characteristics of the demand and supply schedules on both the commercial and recreational side, determine the respective marginal benefit values of commercial and recreational sectors, there is a need to identify the key underlying drivers of the demand and supply schedules. These underlying drivers are discussed below.

### 2.3.2 The Underlying Determinants of the Primary Drivers

A distinction needs to be drawn between the primary drivers of consumer benefits and producer benefits and underlying factors that cause these primary drivers to change. This is discussed in the following sections.

### 2.3.3 Shifts in Catch Demand

There are underlying drivers that cause a fundamental shift (upwards or inwards) in the demand curve for the commercial and recreational catch from a fishery. We know from observed behaviour that factors, other than changes in the retail price of fish or the cost of going recreational fishing, can explain, for instance, the upward shift in the demand curve (or increased demand) for fish illustrated in Figure 8 below for the commercial sector. An equivalent analysis applies to the recreational sector.

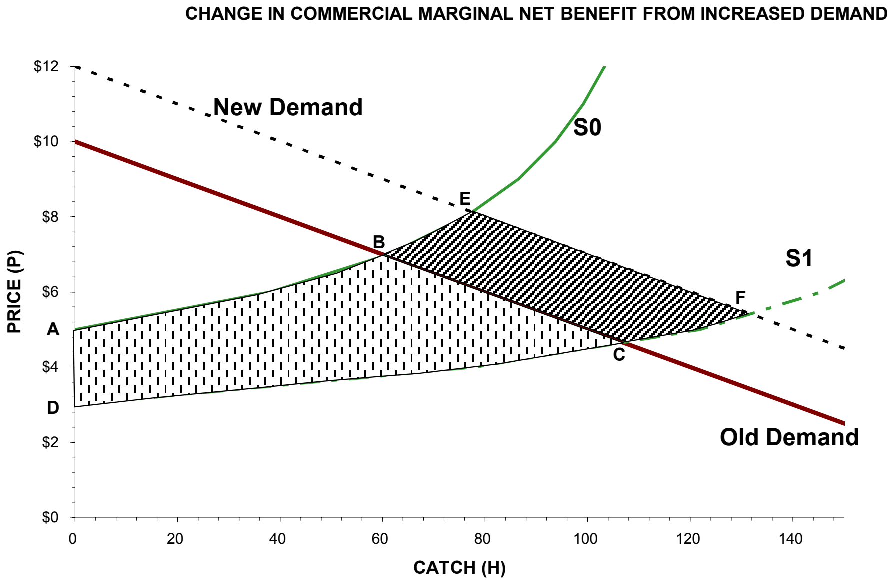



**Figure 8: Increased Demand**

There are a number of factors that the position of a demand curve for a particular species depends upon. These factors include:

- changes in real per capita incomes. For instance, we know from our own behaviour that an increase in real incomes will normally tend to increase the amount we are willing to buy of any good or leisure experience. However, in the case of food items like fish, 'retail' consumer demand tends to be less responsive to income changes, although this may be different for individual species, particularly species highly valued by domestic 'retail' consumers where demand may be more responsive to income changes. This may also be the case for specie highly sought after by recreational fishers because of the greater utility derived from catching experience and/or the catch.
- population growth which can have the effect of increasing total demand for fish by domestic 'retail' consumers or and those seeking a recreational fishing experience;
- a change in taste or preference for fish as, for example, medical evidence of particular health benefits of consuming fish or unique characteristic perceived to be associated with a particular fish specie can change individual 'retail' consumer's preferences in favour of consuming the fish or even those of individual recreational fishers in catching the fish. Also, for instance, the young or 'baby boomers' entering retirement may not hold recreational fishing preferences as strong as those which existed among their predecessors; and

- changes in the demand for competing or substitute products. For instance, a change in the price of red or chicken meats can affect the demand for fish. A fall in the price of red meats can result in a reduced 'retail' consumer demand for fish. Similarly, if the cost of other recreational pursuits falls, then recreational fishers may substitute away from the existing fishing activity for the alternative leisure pursuit by putting reduced time and resources into the recreational fishing activities.

Shifts in a demand schedule, as factors other than the 'retail' price changes for fish from a particular fishery or the cost of recreational fishing experience in that fishery changes, must be carefully distinguished from movements along a demand schedule as the cost of purchasing the fish or attaining the recreational fishing experience changes. A shift in the demand schedule, as shown in Figure 11 above, is distinctly different to a movement that can occur along a particular demand schedule in responses to aforementioned changes that have more to do with the law of diminishing marginal utility.

### 2.3.4 Effects of an Increased Availability of Stock

This is illustrated in Figure 9 below, where for instance the impact of a greater allocation of the resource stock to the commercial or the recreational fishing sector is depicted as a downward shift of the sustainable commercial or recreational catch supply from S0 to S1. Ultimately a greater allocation of the resource stock to the commercial fishing sector can reduce the average and marginal cost of any given level of sustainable catch. This is also true for the recreational sector where an increased allocation can theoretically reduce the average and marginal cost of any given sustainable level of catch. Given a partly elastic demand curve, this supply curve shift will result in an increase in the level of the sustainable annual catch, and a reduction in the retail price paid per unit of catch, or, in the case of recreational fishing, the cost per unit of catch. Consumer surplus will increase by an amount represented by the area XBCY. Depending on parameter values, producer surpluses may increase or decrease. In Figure 9, producer surpluses before the increased stock allocation is represented by the area above the supply curve S0 and bounded by AB and the price line connecting B to the price axis., and after the increased stock allocation by the area above S1 and bounded by DC and price line connecting C to the price axis. Either area may exceed the other. However, the combined impact on consumer surplus plus producer surplus is unambiguously positive, and represented by the area ABCD.

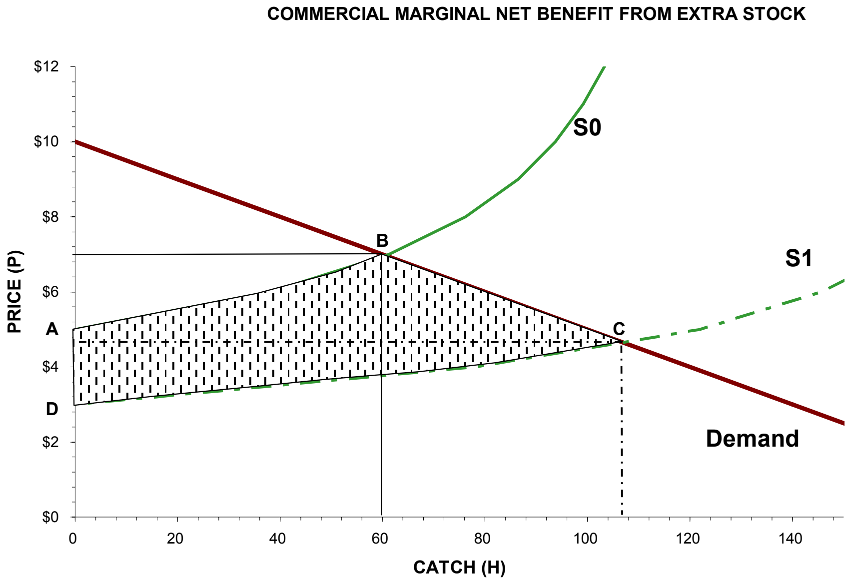



**Figure 9: Marginal Net Benefit from Extra Stock**

Conversely, a reduced stock allocation to commercial or recreational sector has the opposite impact. Again, using Figure 9 above, and thinking of the reduced allocation being depicted by an upward shift of the sustainable catch supply from S1 to S0. In this case, a reduced allocation of the resource stock to the can ultimately increases the average and marginal cost of any given level of sustainable commercial or recreational catch. Given a partly elastic demand curve, this upward supply curve shift will result in a reduced level of the sustainable commercial or recreational annual catch, and an increased retail price paid per unit of catch, or in the case of the recreational fishing sector, the cost per unit of catch. Consumer surplus will decline by an amount represented by the area XBCY. Depending on parameter values, producer surplus may increase or decrease.

In Figure 9, while the gain or loss in producer surplus is unclear in the presence of the reduced stock allocation, the combined impact on consumer and producer surpluses is unambiguously negative, and represented by the area ABCD.

However, both elements may not be present in all fisheries. For instance, there are fisheries where the allocated catch for commercial fishing is not consumed domestically, but, partly or wholly, destined for export (that is, consumption elsewhere). In these circumstances the marginal net benefits from commercial use are those solely attributable to production (that is, the harvesting, processing and exporting as appropriate) and there are no benefits attributable to domestic 'retail' consumption.

### 2.3.5 Changes in Industry and Recreational Fishing Costs

We know from past experience costs of harvesting, processing, distributing and retailing the commercial catch can change over time as illustrated in Figure 10 below. Similarly, we also know the time and costs of going recreational fishing can increase over time. The cost changes can have the effect of increasing the average and marginal cost or sifting the supply curve upwards to the left if there are not offsetting gains from technological improvement (see below).

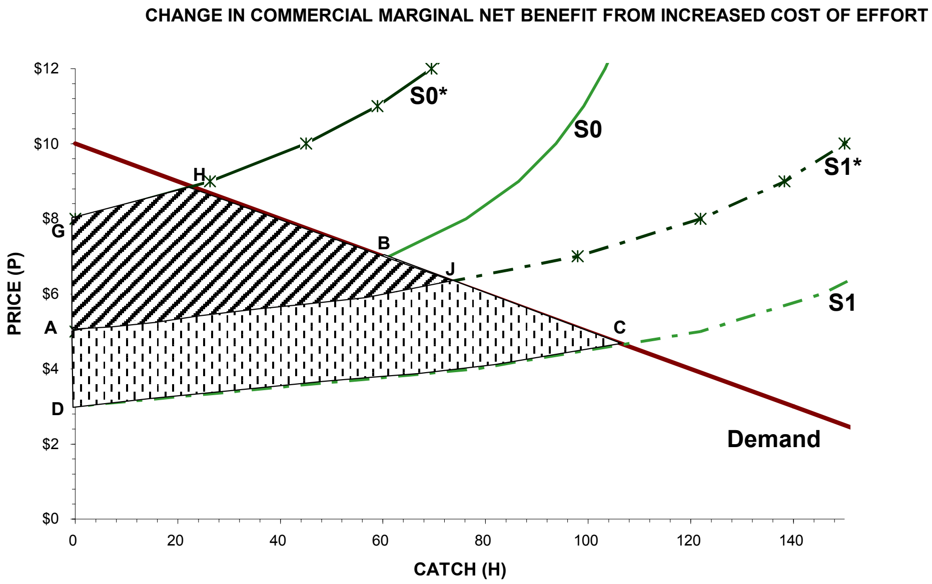



**Figure 10:Changes in Marginal Net Benefit from Increased Production Costs**

### 2.3.6 Changes in Technology

Technological change through improved boats, gear and other equipment in fish harvesting, processing, distribution and retailing and through improved fishing, processing, distribution and retailing methods can reduce the average and marginal costs of commercial caught catch. Similarly, improvements in boats, gear, and other equipment used by recreational fishers can reduce the average and marginal cost of recreational catch.

These technological improvements can, as illustrated in Figure 11 below, shift the supply curve downward and increase the producer surpluses from a commercial catch or net benefits attributable to production. Or, in the case of recreational fishing, reduce the cost per unit of catch and increase the consumer surpluses, as those attributable to supply are not easily separated for recreational fishing. This will occur where the productivity gains from technological advances exceeds any production cost changes.

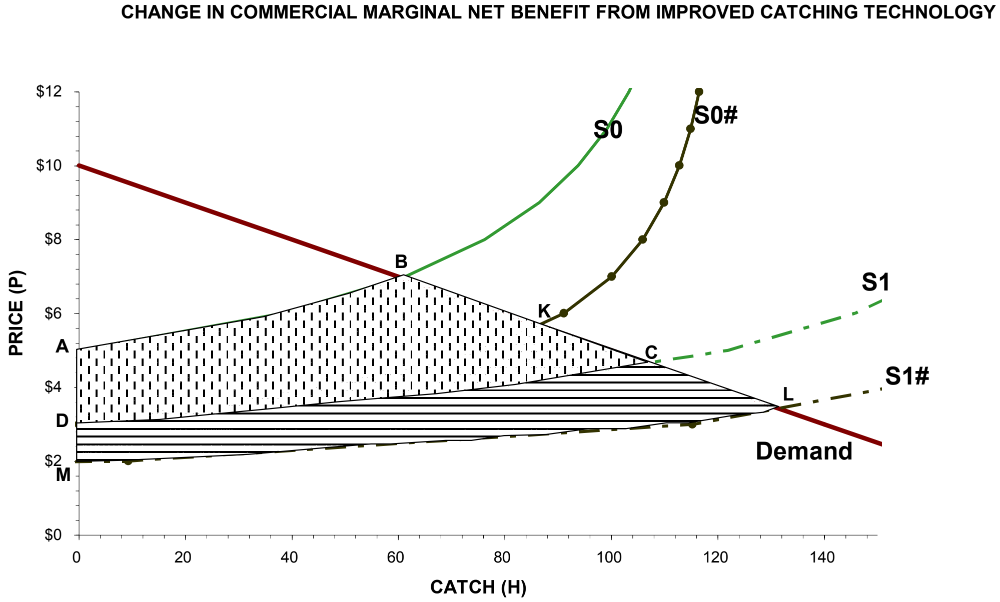



**Figure 11: Changes in Marginal Net Benefits from Improved Technology**

## 2.4 Underlying Determinants of Key Drivers in an Open Economy

In Australia, we operate in open economy where the Commonwealth Constitution guarantees free trade and the free movement of people among and between the Commonwealth, States and Territories. The barriers to external trade are virtually non-existent provided certain standards relating to health, disease and labelling are meet or to overseas tourists provided certain entry conditions are satisfied.

Developments outside a State's economy can impact on the marginal net benefits from commercial and recreational fishing for fish stock taken from a fishery managed within that State's jurisdiction. This can arise in following ways.

### 2.4.1 Availability of Imported Fish or Fishing Experience

On the commercial side, an increased availability of imported fish (from wild capture fisheries, or, more likely, fish farming elsewhere given wild capture fisheries around the world tend to be at maximum sustainable yields) to that State's domestic consumers will result in an externally or import driven downward shift in the supply schedule or an increase in fish supplies available locally. This is illustrated in Figure 12.

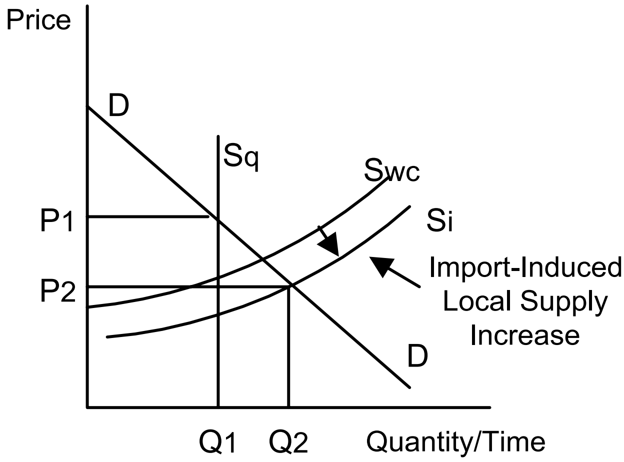



**Figure 12: Impact of an Increase in Imported Fish Supplies**

All other things unchanged, this will affect prices that the locally caught fish substitute may have been able to achieve otherwise. As illustrated in Figure 12 this can reduce the local price from P1 to P2 which in turn impacts on producer surplus from the locally caught fish or the net benefits attributable to production.

However, the net benefits attributable to domestic consumption will be higher than they would be otherwise. Illustrated in Figure 12 this is because the domestic price is lower (P1 to P2) across a larger volume (Q1 to Q2) than would otherwise occur in the absence of these external fish supplies. This has not changed the overall benefit from local catch but has changed the distribution of the total benefits as between producer and consumer surplus.

In these circumstances, the commercial marginal net benefits from the locally caught stock may rise or fall depending the parameter values. That is, whether the any decline in the marginal net benefits attributable to production or changes in producer surplus at the margin is being outweighed by any increase in the marginal net benefits from domestic 'retail' consumption or the increase in the consumer surplus at the margin.

Similarly, the time and cost of a recreational fishing experience elsewhere (inter-State or overseas) may become cheaper and more attractive to local recreational fishers than one in a local fishery. These fishers may substitute the alternative, competitive, recreational fishing experience for one in the local fishery. This will reduce the recreational fishing demand in the fishery and the marginal net benefit of recreational fishing in the local fishery.

### 2.4.2 Impact of External Production Expansions on Export-Oriented Domestic Fisheries

Another way is the impact of external developments that can impact on producer surpluses for a jurisdiction's export oriented fisheries. For example, a rapid expansion in farmed abalone overseas of a species similar to that taken from an Australian fishery may reduce market share of Australian abalone and export prices received. This will reduce the marginal returns for Australian caught abalone and thus impact negatively on the producer surplus in the Australian fishery or the commercial marginal net benefits attributable to the local stock taken from the Australian fishery.

Depending on the extent of price impacts of this increased availability of overseas-farmed abalone, this may see Australian caught abalone diverted to local domestic markets. In that case there may be commercial marginal net benefits attributable to domestic consumption that did not exist previously and that now need to be taken into account.

The export returns are sensitive to exchange rate changes. The dynamic modelling should take a longer-term view of exchange rates that reflect the underlying strengths of Australia's respective trading partners rather than short-term fluctuations. Information on appropriate direction of longer-term rate can usually be obtained from official sources such as the Treasury Departments and the Reserve Bank of Australia.

### 2.4.3 Impact of Growing External Demand on Domestic Fisheries

If demand for fish elsewhere in growing faster than available fish supply, the export prices will rise and if the local prices are less than the net returns available from export, local supplies will be diverted to export until the local prices rise to the point where they equate to the export price. This will reduce local consumer surplus but increase the producer surpluses for fish taken from the local fishery.

Likewise, a local fishery may become increasingly attractive as a fishing destination experience for interstate and international fishers. This adds to the fishing demand for local fish stock. This is no different from commercial catch directed to 'retail' consumers elsewhere from an export-oriented fishery.

### 2.4.4 International Trade Reforms

Changes in the world-trading environment resulting from bi-lateral and multi-lateral trade agreements may also impact on the commercial marginal net benefits for locally caught fish. For instance, trade reforms that reduce agricultural subsidies and trade barriers in the EEC and the US may open up longer-term trade opportunities for Australian produced red meats that could see Australian red meats redirected to overseas markets. This may result in the Australian domestic red meat prices rising that may increase the Australian domestic demand for substitute products like fish.

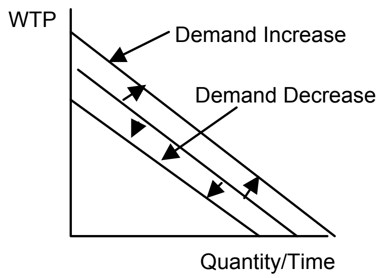
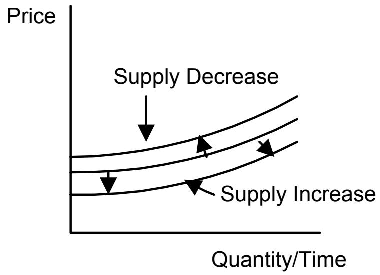
## 2.5 Symmetrical Nature of Underlying Drivers

The discussion above highlights the symmetrical nature of the primary and underlying drivers of the marginal net benefits form commercial and recreational fishing. This symmetry is demonstrated by the following flow chart.

The key variables driving changes in the marginal net benefits from commercial fishing can be found to have parallel variables operating on the recreational side. For instance, we know rising real incomes and population growth increase the 'retail' consumer demand for fish. And, we also know these variables are a growing recreational fishing demand. The underlying consideration is which one is growing fastest. On the supply side we know the industry costs are increasing as are the time and cost associated with recreational fishing. But we also know technological change is working to reduce the average and marginal costs of both commercial and recreational side.

The following Chapters add the fisheries management context to the general demand and supply analysis. This approach outlines the way in which the introduction of fisheries management rules impact on the drivers of the future direction of marginal net benefits from commercial and recreational fishing.

**Figure 13: Marginal Net Benefit Drivers for Commercial and Recreational Fishing**

| Benefits | Underlying Drivers in the Commercial Seafood Sector | Primary Drivers | Underlying Drivers in the Recreational Fishing Sector |
|---|---|---|---|
| Net Benefits Attributable to Consumption | Underlying drivers of 'Retail' consumer demand shifts:<br>• Real per capita income growth<br>• Population Growth<br>• Taste and preference changes<br>• Competitive Product Changes | Demand Schedule Shifts<br> | Underlying drivers of recreational fishing demand shifts:<br>• Real per capita income growth<br>• Population Growth<br>• Participation rates<br>• Taste and preference changes<br>• Competitive Leisure Product changes |
| Net Benefits Attributable to Production | Underlying drivers of Harvest and Post-Harvest Supply Shifts:<br>• Production cost changes<br>• Productivity gains<br>• Scale economies/diseconomies<br>• Alternative supply increases | Supply Schedule Shifts<br> | Underlying drivers of Recreational Fishers' and Charter Boat Operators supply schedules:<br>• Production cost changes<br>• Productivity gains<br>• Scale economies |

# 3 A Demand Supply Analysis Approach to the Future Direction of Commercial Marginal Net Benefit

In the previous section a general demand and supply analysis view was presented. Commercial situations are typically constrained by various management regimes. Whether these regimes are input or output based, the effect is to cap the allowable catch. In moving toward the development of a model which can be used to estimate commercial net benefit and the optimal resource allocation path, we need to allow for the operation of these constraints. This is then the basis for the implementation of the empirical analysis.

The situation that applies in wild capture fisheries can be analysed in the context of supply and demand. As illustrated in Figure 14 below, there will be an underlying supply schedule, $S_t$, and an underlying demand schedule $D_t$ for a range of catch volumes of a fish species taken from a fishery regardless of whether constraints apply in the fishery. This is a theoretical representation and in practice the real demand and supply schedules can present with different characteristics to what might be presented in economic theory. The key is to identify the characteristics of the underlying supply and demand schedules for the fish taken from a fishery.

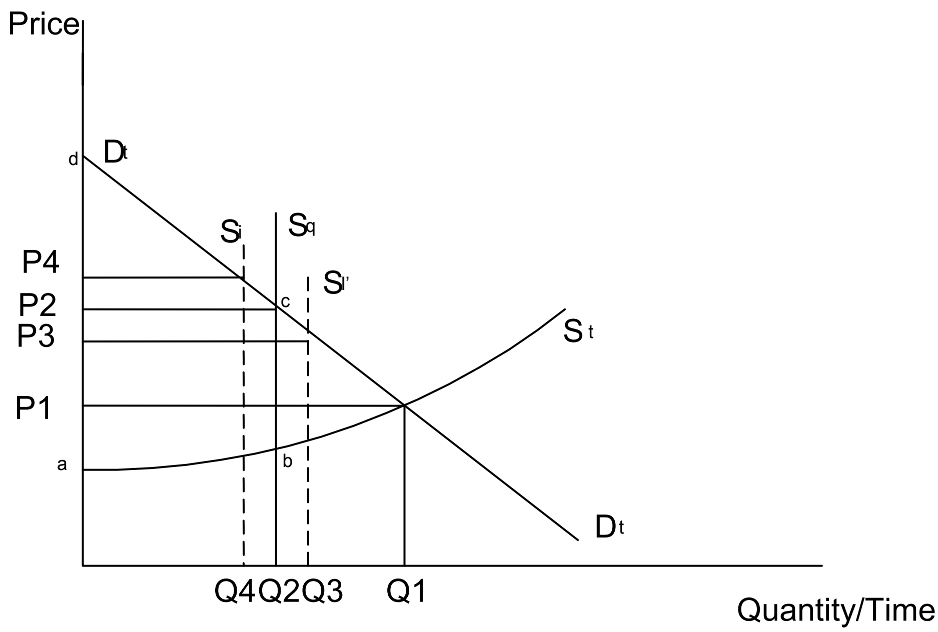



**Figure 14**: Hypothetical Demand and Supply Schedules for a Fish Species

Figure 14 illustrates that, without constraints, consumers would prefer to be at quantity Q1. If the sustainable catch level were to the right of, or greater than, Q1 then there would be no need for restrictions to apply because catches are kept within sustainable levels by market forces.

However, the experience observed in wild capture fisheries typically involves restrictions on catch and/or inputs used to harvest fish. These are illustrated in Figure 14 in the form of a single catch volume quota represented by supply schedule $S_q$ or an indirect constraint on catch through input controls. The later tend to constraint catch within a sustainable range dictated by the biology applying in the fishery. This in represented in Figure 14 by supply schedules $S_i$ and $S'_i$.

The benefits to society are measured by the consumer surplus, P2cd, plus the producer surplus, abcP2, under the quota-constrained catch Sq and represented by the area abcd. In the case of the input controlled fishery these benefits will tend to fall within a range represented by the supply schedules Si and S'i in Figure 14.

## 3.1 Demand Shifts by 'Retail' Fish Consumers

### 3.1.1 Underlying Drivers of 'Retail' Fish Demand

There are underlying drivers that cause a fundamental shift (upwards or inwards) in the demand schedule for the commercial catch from a fishery over time. We know from observed behaviour that factors, other than changes in the own price of fish, can explain, for instance, the upward shift in the demand schedule (or increased demand) for fish is illustrated in Figure 15 below.

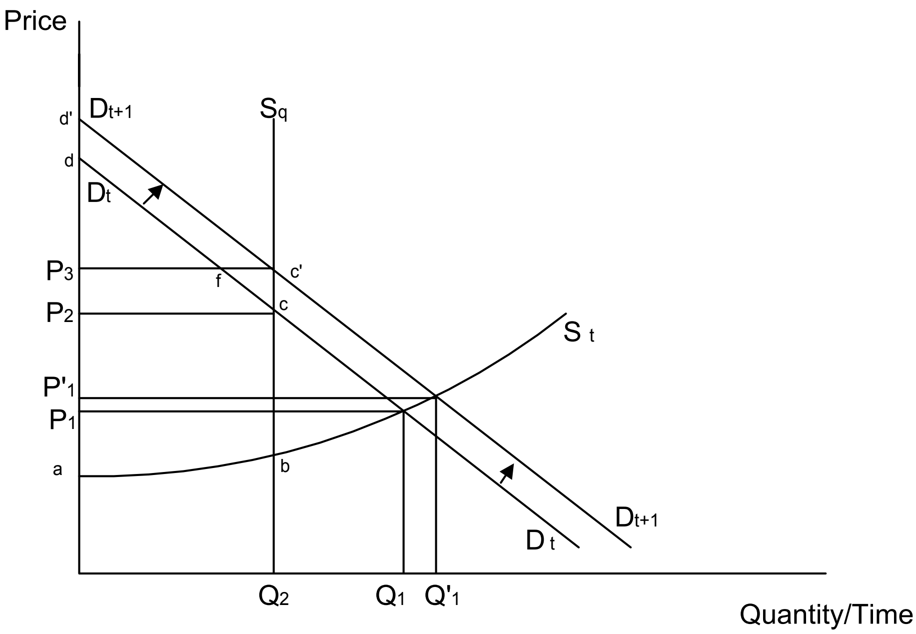


**Figure 15: Increased Demand for a Fish Species from on Output-Controlled Fishery**

As explained in section 2.3.3 above, there are a number of factors that influence position and slope of the demand curve for a particular species. These factors include changes in real incomes of domestic consumers, population growth which can have the effect of increasing total market demand for fish, changes in taste or preference for fish and changes in the demand for competing or substitute products.

The key underlying drivers tend to be real income increases and population growth. As a broad rule of thumb in Perth for instance, population growth is running at an annual rate of around 1.5%, whilst real incomes are increasing at around 2.5% annually. Assuming the income elasticity of demand for fresh fish in Perth is around 0.30, then the underlying growth in demand for fresh fish is increasing demand or shifting the demand schedule outwards at a rate of around 2.25% annually all other things being unchanged.

### 3.1.2 Impact of Demand Shifts under Output and Input Management Regimes

Figure 15 above shows that, without constraint, the long-term market equilibrium would see catch rise from quantity Q1 to Q'1 and price would increase from P1 to P'1. However, where the total allowable commercial catch is constrained by a quota, as represented by Sq in Figure 15 above, the response to a demand increase or shift in the demand schedule from Dt to Dt+1 will be a rise in price of the fish from P2 (being the price supply Sq at demand Dt ) to P3. This will ration the increased demand to the constrained commercial catch Sq.

In consequence, the consumer surplus will decline and represented by the triangle cc'f. On the other hand, the producer surplus will rise as represented by the rectangle cc'P3P2, assuming there is no change to the underlying supply schedule St. As this is greater than the loss of consumer surplus in this illustrated example, the commercial net benefit will rise and represented by the area cfP3P2. The extent to which this is the situation will depend on the relative elasticities of the demand and supply schedules.

The impact of a demand shift in an input-controlled fishery will be not dissimilar, except the price will vary within a higher price range as illustrated by Figure 16 below.

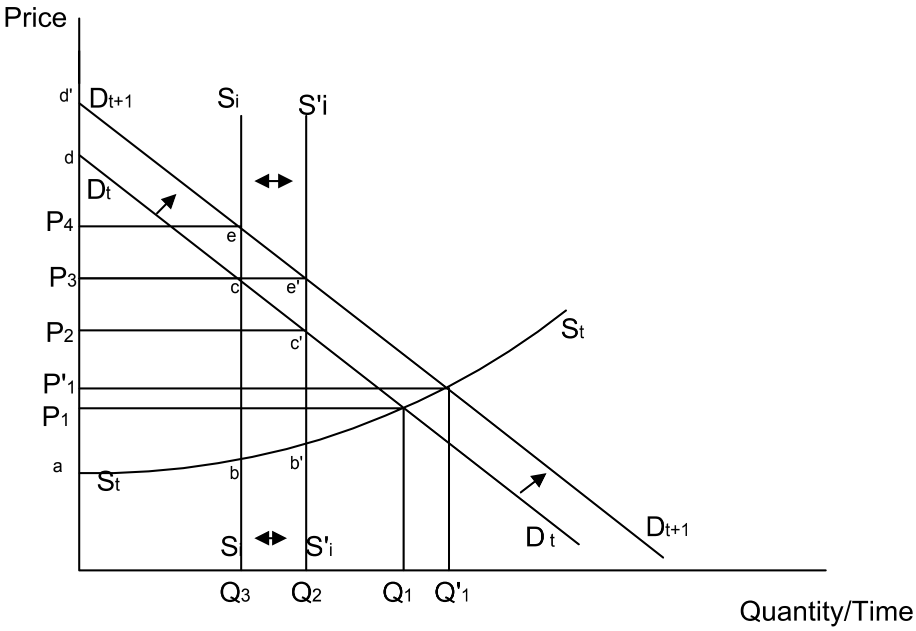



**Figure 16: Increased Demand for a Fish Species from an Input Controlled Fishery**

Under an input-controlled fishery where the total commercial catch is typically constrained within a sustainable range driven by the biology operating in the fishery as represented by the supply schedules Si Si and S'i S'i. Demand Dt is rationed to the available supply by prices ranging between P2 and P3 where the supply schedule S'iS'i and SiSi respectively intersect the demand schedule Dt. If the demand increased from Dt to Dt+1 then the new price range to ration the available commercial catch constrained by the input controls at SiSi and S'iS'i would rise to P3 and P4. Again the consumer surplus would decline and producer surpluses would rise and, in this illustrative example, the rise in the producer surplus will be greater than the decline in consumer surplus, resulting in a rise in the commercial net benefit.

## 3.2 Supply Shifts

### 3.2.1 Underlying Drivers of Supply Schedules

In a dynamic economy shifts in the supply schedules can also be taking place concurrently with changes on the demand side. These underlying drivers that can result in supply schedule shifts need to be identified and measured in a way that can be aggregated to determined the likely overall impact on the supply schedule and enable comparison with the changes occurring on the demand side.

Apart from over exploitation, which is a sustainability issue not an allocation issue, the key underlying drivers of supply schedules shifts are changes in harvest and post harvest costs of production, productivity gains in the harvest and post-harvest activities, and supply increases from aquaculture developments (locally or elsewhere) for fish species that are strong substitutes in consumption for the particular species being considered.

These underlying drivers can work to shift the supply schedule in opposite direction over time as illustrated by Figure 17 below.

As Figure 17 shows, rising production costs put upward pressure on the supply schedule as represented by Si, whilst productivity gains on the other hand place pressure on the supply schedule to shift outwards as represented by Sp. The net impact on the supply schedule over time depends on whether the percentage increase in industry (harvest and post-harvest) productivity is greater or less than the percentage change in production costs. If the percentage rate of productivity gains are exceeding the percentage rate at which production costs are increasing, then the supply schedule will shifting outwards or lower marginal costs and vice versa.

At the margin, production costs tend to be driven by labour costs, particularly where remuneration is coupled to catch value and energy costs. In the case of energy costs, there are useful benchmark indicators of the likely future direction of changes in energy costs that when applied to the relative significance of energy costs in the harvest and post-harvest costs will provide at least a lower order estimate of the likely rate of production cost increases.

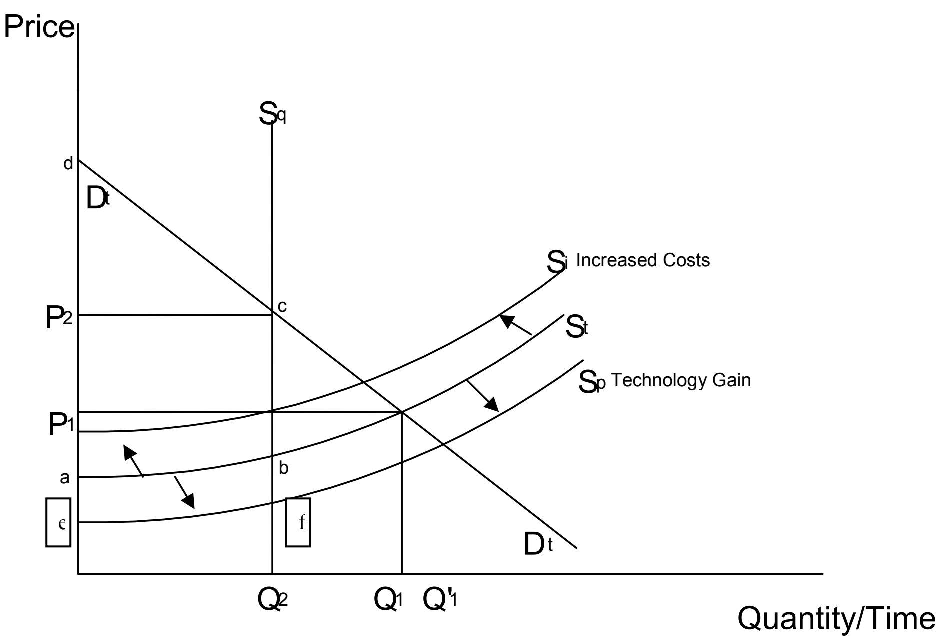



**Figure 17: Impact of Production Cost Increases and Productivity Gains on Supply Schedules**

### 3.2.2 Productivity Gains under Output and Input Management Regimes

There is a significant difference between the impact of 'technological creep' in the harvest sector under an output-controlled compared to an input-controlled fishery. In Figure 17 above, where an output control applies as represented by Sq, a downward shift in the supply schedule due to productivity gain shown by Sp will have the impact of increasing the producer surplus from abcP2 to efcP2 all other things remaining unchanged.

However, productivity gain in an input-controlled fishery will initially reduce the underlying supply schedule from St to St+1 as shown in Figure 18 below. However this productivity gain also shifts the constrained supply schedules SiSi and S'iS'i to the right or increases the potential catch range to S'it+1 and S"it+1 as shown in Figure 18 below. As this can pose a risk to the sustainability of fishery over time, the net benefits from productivity gains typically become consumed by changes to the management rules operating in the fishery to keep commercial catch within sustainable bounds, that is, the rule changes are designed, in effect, to contain the supply schedule at or about St over time.

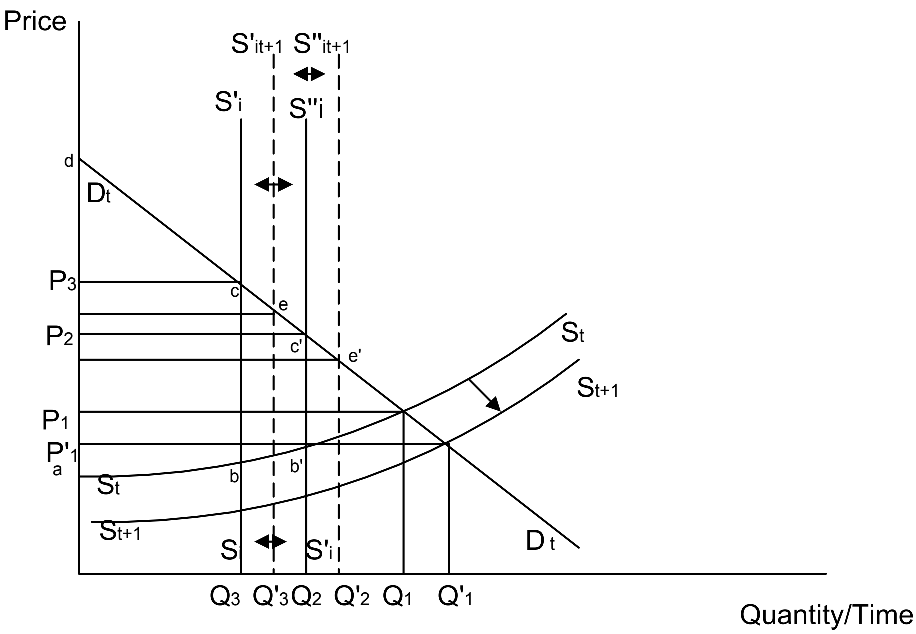



**Figure 18: Productivity Gains in an Input Controlled Fishery**

Unlike the output-controlled management regime, the benefits of productivity gain are arguably not reflected in increases to producer surplus in the longer term under an input-controlled fishery. Indeed, there is a risk that adjustments to the input controls can overshoot, leaving production cost increases to drive the supply schedule inwards and thus reduce the producer as well as the consumer surplus and the overall benefits from commercial use.

### 3.2.3 Impact of Aquaculture Developments

Another key underlying driver that can cause increased supply or shift the local supply schedule outwards is aquaculture developments either locally or externally of fish species that are the same species or those that are strong substitute for the species under consideration. The entry of aquaculture produced competitive or substitute fish will introduce supply schedule Sa as illustrated in Figure 19 below where a 'wild capture' fishery is subject to output controls. This is represented in Figure 19 by the underlying supply schedule Swc and the quota-controlled catch Swcq at quantity Q2.

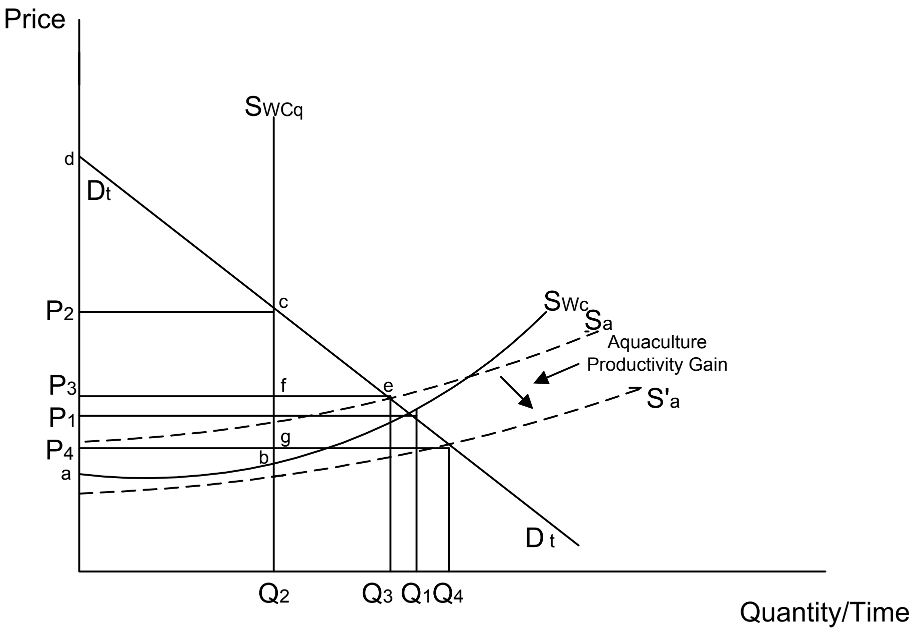



**Figure 19: Impact of Aquaculture Developments on Supply**

The introduction of farmed fish, Sa in this illustration will, result in a greater quantity of local demand Dt being satisfied. This is reflected by the point at which the aquaculture supply schedule Sa intersects the local demand, that is, a point e in Figure 19. This will see the local price fall from P2 (before the entry of farmed fish) to P3 (following the entry of farmed fish). This means the quantity of local demand satisfied by the wild capture fishery is Q2. The difference between Q2 and Q3 is satisfied by aquaculture supplies.

The aggregate commercial net benefits from the wild capture fishery remain the same as represented by the area abcd, except the distribution of the benefits has shifted in favour of increased consumer surplus and reduced producer surplus, particularly in the harvesting sector. If productivity gains in aquaculture were to shift the aquaculture supply schedule below the underlying wild capture supply schedule as represented by S'a in Figure 19 above, then the producer surplus from wild capture declines even further and an increased share of larger domestic demand responding to lower price will be meet from aquaculture supplies.

In general, the entry of competitive aquaculture supplies does not alter the overall commercial net benefit from wild capture fishery but changes the distribution of the commercial net benefits away from those attributable to production in favour of those attributable to consumption from wild capture fishery. However, a critical point could be reached where, in response to rapidly increasing competitive supplies of farmed fish, the prevailing local price is expected to fall below the marginal cost of harvesting the wild capture supplies. In that case, the commercial harvesting of the wild capture supplies will become increasingly unprofitable to the point where all local demand will be satisfied by aquaculture.

In considering the impact of aquaculture on the commercial net benefits from wild capture stock, a key issue is identifying whether this critical point is being reached. Otherwise, the impact of increasing supplies of substitute fish from aquaculture simply changes the distribution and not the level of the aggregate net benefits from the wild capture fishery.

### 3.2.4 Changes in Export Markets

For fisheries with an export focus, the key underlying drivers will be shifts in world demand and supply. And the underlying drivers will be similar to those mentioned in Sections 2.1 and 2.2 above but on international scale.

If wild capture fisheries worldwide are generally at the maximum sustainable take, then the main drivers in the longer term will be the growth in world demand for fish dependent on population growth and the increase in world supply of aquaculture.

As a general starting point, the impact of international developments could be included in the conceptual framework as a shift in the demand for fish. If world demand for the fish specie is growing faster than world supply, then the demand for fish from the local fishery will increase or the demand schedule will shift outwards and vice versa. In the latter case, a rapid growth in world aquaculture production will not only impact on world prices but may also result in the world demand for fish from our export fisheries becoming more elastic. Increased supply of fish, primarily through aquaculture, would shift supply in the rest of world out and decrease prices.

Demand from the rest of the world would shift away from local fisheries and the commercial demand curve would contract reducing the net benefit associated with local wild capture. This is illustrated in

Figure 20 below.

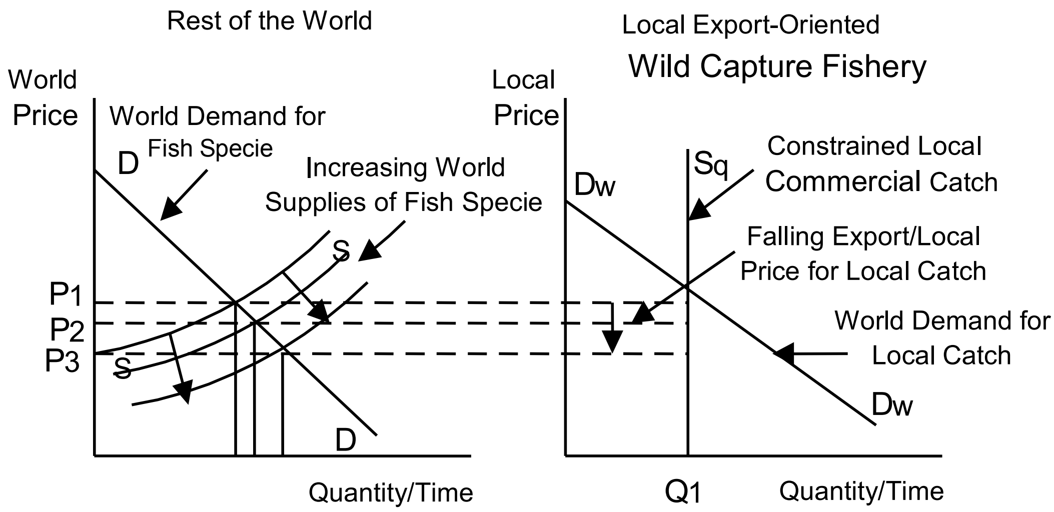



**Figure 20: Effect of Increasing World Production on Domestic Demand**

# 4 Evaluating the Future Direction of Recreational Marginal Net Benefit

As with then previous section, we need to understand the key primary and underlying drivers that drive recreational marginal net benefits, the interactions between them and the set of indicator variables that can be used in a practical sense to quantify the likely impact on the future direction of recreational marginal net benefits. It is this expected change in the level of marginal net benefits that will, along with the equivalent measure on the commercial side, determine the time path of the allocation of the fish resource.

As with the previous section the key is that the allocation regime fixes the supply of fish for recreational purposes at any point in time. Hence the general supply analysis of Section 2 is replaced by a supply side constraint.

In thinking about the recreational side in a demand and supply context we need to recognize that while as a general rule, there are no well defined markets for buying and selling recreational fish catches or the recreational fishing experience, the basic forces inherent in demand and supply analysis still operate.

On the demand side we can assume that recreational fishers make decisions about fishing (location, time, catch, gear etc) to maximize their individual well being. That is they want to maximize their utility. Just as with other consumption decisions they do this subject to a budget or income constraint and are forced by this constraint to make trade offs within the fishing activity and between fishing and other recreation and consumption pursuits to which they could allocate their time and money.

On the supply side, greater levels of activity (catches) are likely to come at increasing marginal cost. To catch additional fish, fishers may need to spend more time, use better gear, travel farther to better locations, purchase additional fishing information and this increases the marginal cost. Just as with commercial activity, recreational fishers can experience cost reductions through improved technology and productivity.

We can think of the “price” as a form of generalized cost. This consists of money costs incurred plus time costs incurred to travel and fish.

We need to understand what will tend to increase demand at any given level of “price” and what will tend to increase or decrease the marginal cost of fishing.

## 4.1 Individual Recreational Fisher with Constrained Catch

Figure 21 shows the utility maximizing choice for a consumer whose recreational catch is constrained by say, bag limits. The budget constraint shows the tradeoff between recreational fishing and other consumption and its slope reflects the relative price of each. The recreational fisher would optimize at Q' if there were no catch constraints. In the presence of catch constraints the fisher is limited to Q'' which is less than the first best amount. The individual fisher is prepared to commit more resources (money and time) to catch more fish than the binding constraint allows them to. Consequently, in theory, the recreational fisher would be willing to pay to alleviate the constraint and catch more fish. The willingness to pay is directly linked to the utility loss being suffered. In aggregate demand for recreational fishing exceeds the limited supply.

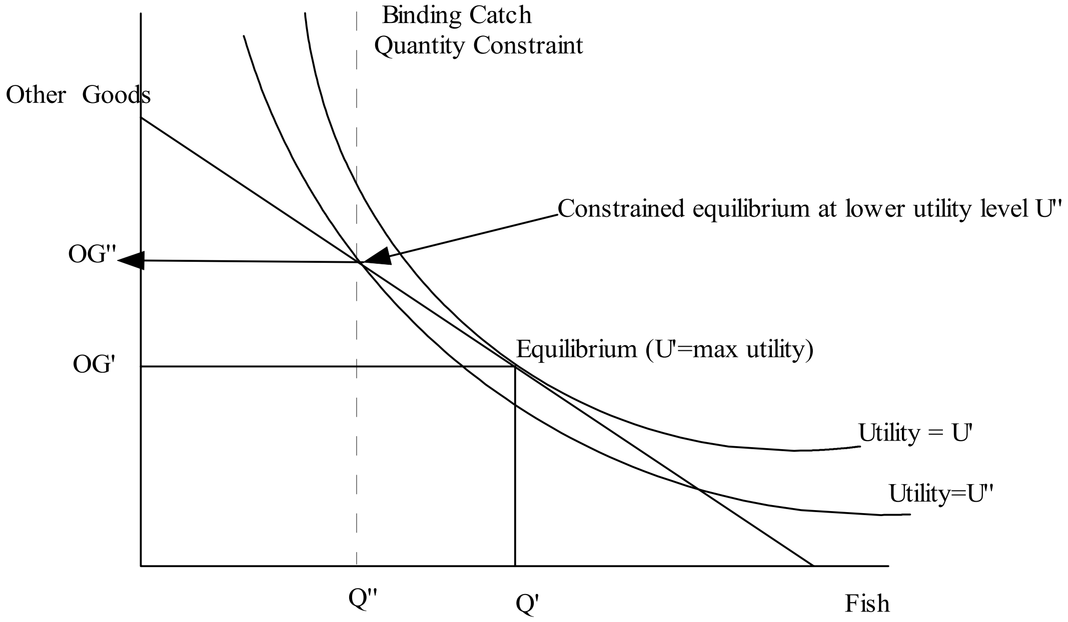



**Figure 21: Typical Constrained Consumer Choice**

The demand for recreational fishing will be influenced by changes in any factors connected to this optimal choice behaviour.

If income increases, then the budget line shifts out expanding the choice possibilities. If recreational fishing is a normal good then this increase in income will increase the optimal level of recreational catch. The demand for recreational fishing shifts out. That is consumers now wish to undertake higher levels of fishing activity at all prices. The aggregate demand for recreational fishing shifts out.

If tastes change the individual fisher's utility curves shift and may change slope. If they shift outwards, then all other things (income and relative prices) given, individuals wish to do more fishing. Again the demand (optimal quantity) for recreational fishing increases. Again if all recreational fishing consumers are affected similarly the aggregate demand curve shifts out.

If the slope of the indifference curves changes, then the relative attraction of recreational fishing compared to other activities changes within the consumer's preferences. In this case, if the change is in favour of recreational fishing, the consumer is now willing to give up more of the consumption alternatives to achieve recreational fishing consumption.

As with commercial fishing in the previous section, the consumer is constrained by the catch limits. Therefore when the optimum consumption level increases as per the above, the individual consumer cannot increase actual activity. The gap between the optimal and constrained optimum quantities increases. In aggregate this means that the gap between aggregate and demand and the allowed aggregate catch increases.

The analysis can be summarized in the following diagram. The vertical axis is the marginal willingness to pay, the "price". Reflecting the basic consumer choice model recreational fishers have a higher marginal willingness to pay at lower quantities of fish caught and this  marginal willingness to pay falls as quantity caught increases.

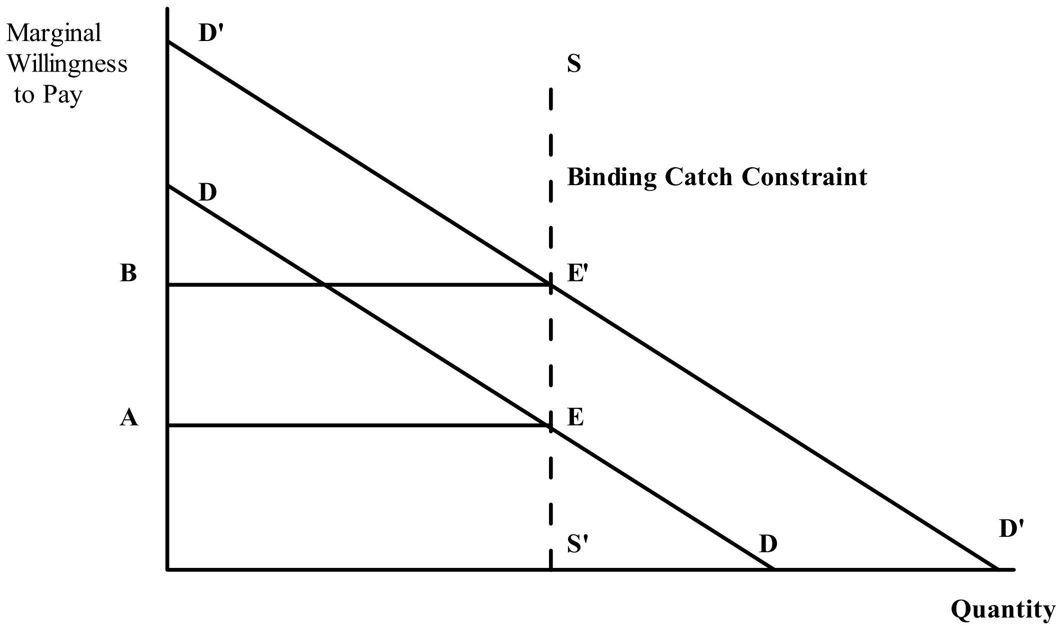



**Figure 22: Increased Demand for a Recreational catch in the Presence of a Binding Catch Constraint**

Based on the individual choice model discussion, there are a number of factors that could drive the demand curve for recreational fishing up. These include:

- changes in real incomes of consumers. An increase in real incomes will normally tend to increase the demand for leisure activities including recreational fishing.

- population growth which results in more fishers wishing to participate in the recreational fishing experience;
- a change in taste or preference which would increase the participation rate by individuals. This is likely to be connected to changing demographic composition
- changes in the prices of substitute products such as alternative leisure pursuits

In Figure 21 the demand curve shifts from DD to D'D'. The effect is to increase the level of unsatisfied demand at the current "price". Given the constrained catch, the marginal willingness to pay increases from A to B. The consumer surplus increases by DEE'D'. That is the valuation of the fish stocks SS' allocated to recreational fishing increases.

Recreational fishing is not a costless experience. Real resources have to be committed as a combination of purchased inputs and time to undertake recreational fishing activities.

As the costs associated with the supply side change the net benefits accruing from recreational fishing will change.

In Figure 23, the effect of a change in costs is illustrated.

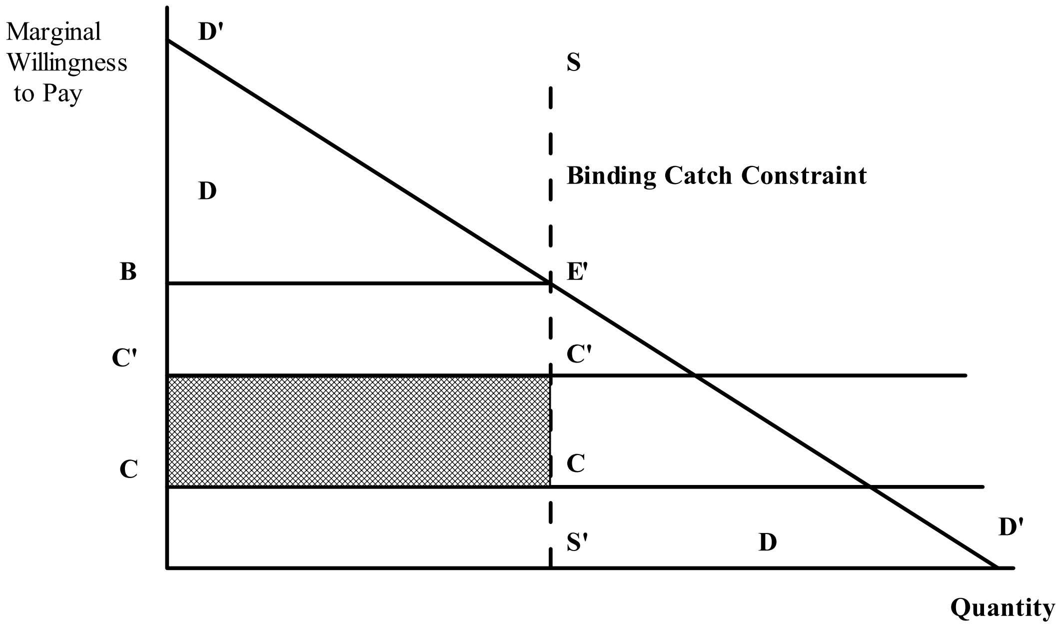



**Figure 23: Affects of Changes in Costs on Net Benefits From recreational Fishing**

Essentially when costs increase from CC to C'C' the net benefits from recreational catch allocation SS' fall by the shaded area.

The driving factors behind changes in the costs of recreational fishing will be related to :

- changes in input costs such as gear prices, bait prices, fuel, boat ramp fees.
- changes in technology that improve productivity such as improved gear design, new gear.
- changes in rules such as site limitation, reduced access areas.

# 5 Modelling the Optimal Time Path of Allocation Adjustments

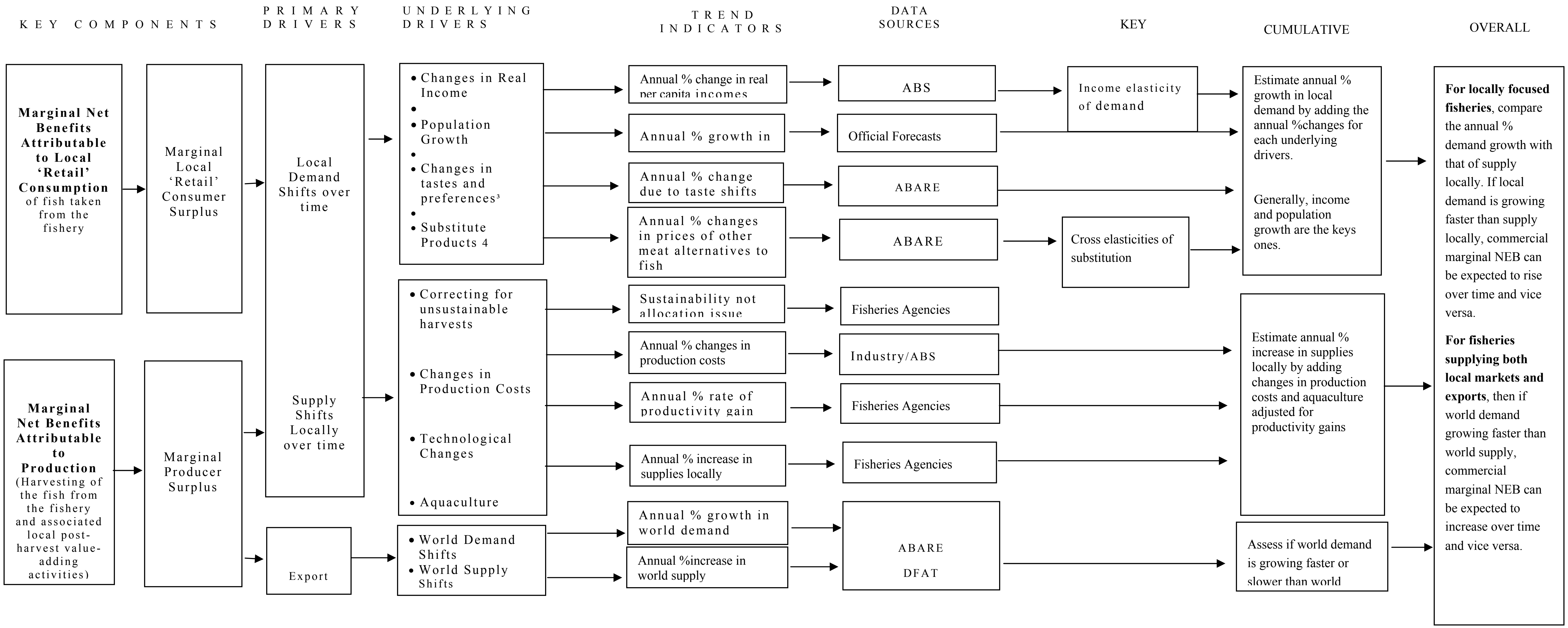
## 5.1 A Schematic of the Modelling Process

The flow chart below provides a conceptual framework that identifies the key primary and underlying drivers of commercial marginal net benefits and that a set of ‘trend indicators’ that can be used to quantify the likely impact of these drivers, both individually and in aggregate, on the future direction of commercial marginal net benefits.

Each of these underlying drivers of the demand and supply schedules can impact differently in terms of shifting the respective schedules inwards or outwards. For instance, productions cost increases push the supply to the left, whilst productivity gains have the opposite impact on the supply schedule. Similarly, population growth and real income increases may collectively drive the demand schedule outward or increase demand, whilst any longer-term fall in prices of products that are strong substitutes for fish in consumption reduce the demand for fish or shifting the demand schedule inwards. The key is to be able to quantify the likely net impact of trends in these key drivers on the respective supply and demand schedules.

In order to do this, the key trend drivers are measured in terms of percentage movements. This allows each of the ‘trend’ indictors to be aggregated to determine the likely future direction and rate at which the respective demand and supply schedules might shift. It also allows a comparison of these cumulative outcomes for both supply and demand to determine the likely overall net impact on the future direction on commercial marginal net benefits established from the application of the static framework

**Figure 24; Gauging and Modelling the Future Direction of Changes in Marginal Net Economic Benefits of Fish Taken From a Local Fishery[1]**




**Notes:** [1] The starting point for this diagram is the base marginal value determined by the application of the static model outlined in previous research by McLeod and Nicholls (op cit 2).

[2] Population growth should be related to the key local markets where the fish is sold. For example, in Western Australia the major local market for fish taken from local fisheries is Perth and population growth in Perth is a key underlying driver.

[3] For example, perceived health benefits from eating more fish may encourage local consumers to substitute more fish for other meats

4For instance, if the EEC and US reformed their domestic agricultural support and trade barriers, there may be increased demand for Australian beef, lamb. pork and chicken meat exports and any resulting increase in Australian domestic retail prices for these meats may see Australian domestic consumers substitute more fish (fresh and processed) in their meat purchases.

5.The key underlying drivers of production costs changes at the margin are generally labour and energy costs. In the catching sector, labour costs as a general industry practice, tend to be linked to the gross value of catch in one form or another.

6.Fisheries Agencies tend to closely monitor 'technology creep' in the catching sector, particularly in input-controlled fisheries in order to contain catch within sustainable boundaries. The benefits of 'technological creep' in these fisheries tend

## 5.2 Time Path of Allocation

There is a need to be able to understand the time path of future adjustment as part of knowing what is an appropriate decision today. The actual time path will depend on the relative magnitude of the shifts in the marginal net benefit functions illustrated above. Combined different relative shift patterns can generate a number of different time paths. Three generic paths are illustrated in the Figure 25, Figure 26 and Figure 27 below.

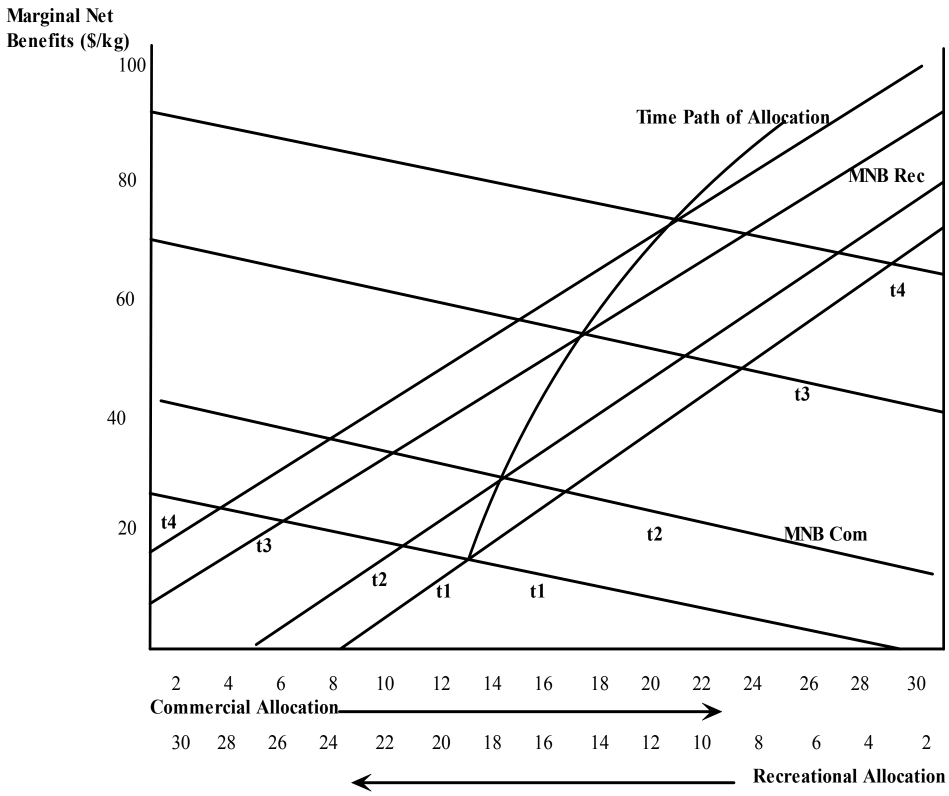



**Figure 25: Optimal Time Path of Allocation When Shift is Toward Commercial Sector**

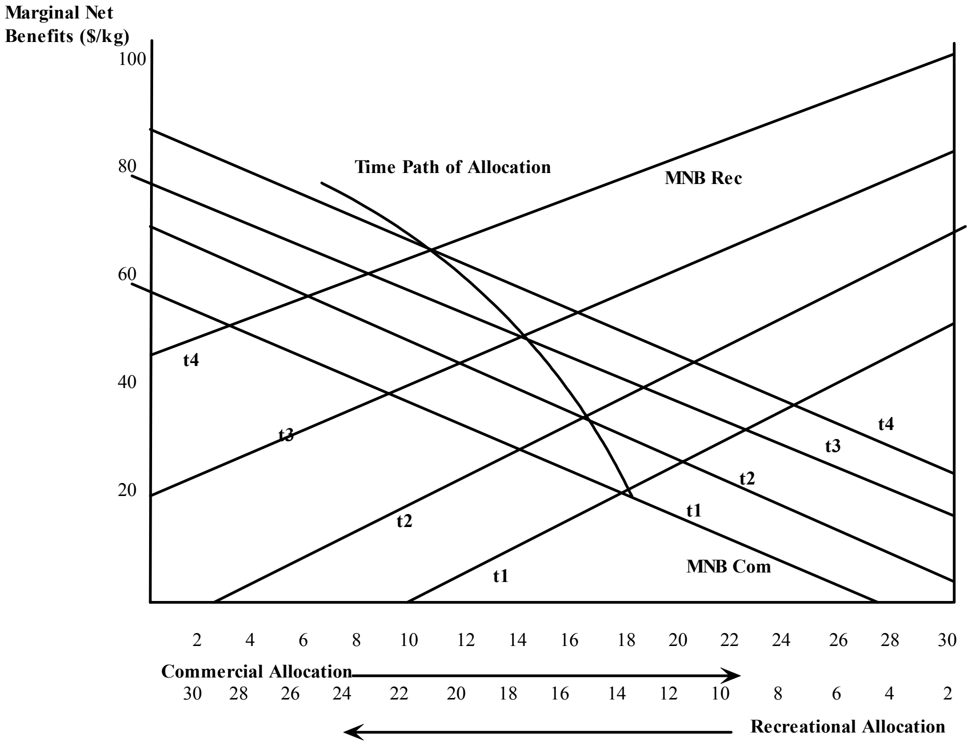



**Figure 26: Optimal Time Path of Allocation When Shift is Toward the Recreational**

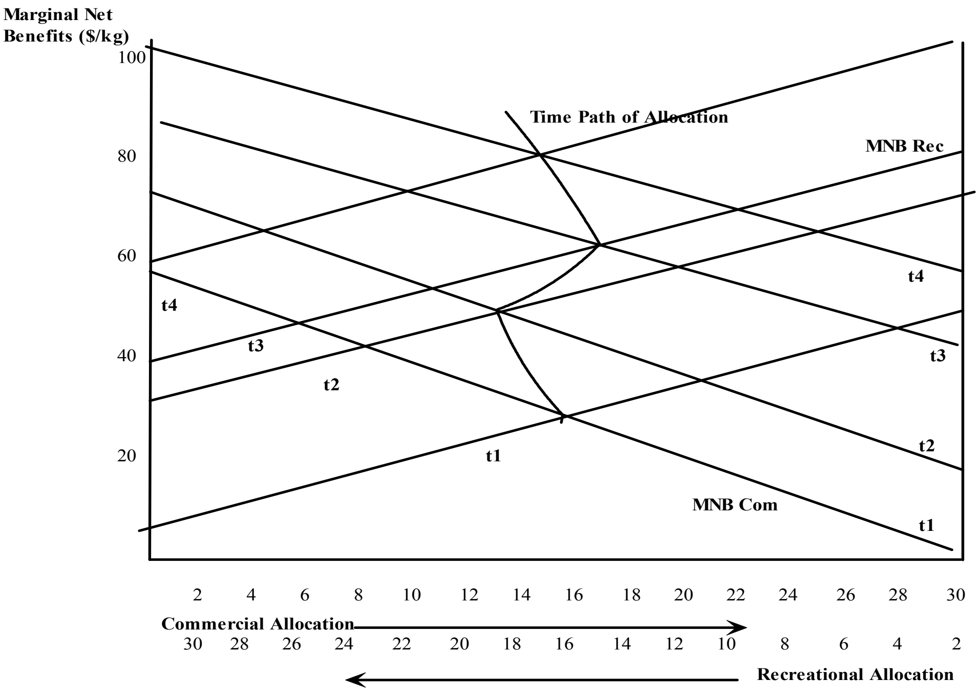



**Figure 27: Optimal Time Path of Allocation When Optimal Allocation Changes Direction**

In Figure 25 the time path of allocation moves toward commercial use over the four time periods t1 to t4. In Figure 26 the time path moves toward recreational use in each of the four time periods and in Figure 27 it swings between the two as we move from time period t1 to t4.

These diagrams assume that we start from the optimal initial allocation but as was pointed out above we may not. Indeed am optimal initial allocation is unlikely in the current environment.

If the time paths are as per Figure 25 and Figure 26and if the initial allocation is sub optimal but should be adjusted in the direction of the time path change to achieve an initial optimal allocation (that is toward commercial in Figure 25 and toward recreation in Figure 26) then the initial decision takes allocation in the right direction. That is everything is directionally consistent.

However, if the initial change is counter to the indicated time path (that is goes toward recreational use in Figure 25 and toward commercial in Figure 26) then we have a more complicated decision. In effect if we know what the time path was we would know that the initial decision would have to be reversed and we would have an estimate of when that would have to occur.

In Figure 27 the problem would be that even if the initial allocation was optimal achieving optimality at a given point of time in the future would require continuous redistribution of fish stock between recreation and commercial fishers.

Responding to the need for frequent adjustment over time, would be less of a dilemma if it were costless both to measure the level of marginal net benefit for each sector, and to re-allocate sustainable annual catch between sectors. In these circumstances maintaining an optimal allocation of the resource stock would be a straightforward technical task requiring neither analysis nor judgment.

However, as the previous study[7] has revealed, this is not likely to be the case. Estimating levels of marginal net benefit can be a costly, difficult and is prone to valuation errors. In its fully fledged form it is unlikely to be something that fisheries managers would wish to do or even could afford to do regularly.

Furthermore, in addition to these costs, transaction costs have to be incurred each time a decision is made to reallocate fish resource stocks from one sector to another. These transaction costs include not only the cost of managing the change process but the costs of policing the changes. As noted in the previous study, there is some fixity of capacity and lumpiness on the commercial side and for some fisheries this is also true on the recreational side. This raises the costs of continuous short run adjustments.

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[7] Op cit 2

Hence, depending on the magnitude of these various transaction costs, it is likely to be impracticable and unrealistic as well as inefficient to continuously readjust the inter-sectoral allocation of the fish resource stock.

To these considerations we can add the purely political considerations which militate against frequent readjustments especially ones which are volatile as shown in Figure 27. Politically as well as economically some allocations or reallocations may be difficult to reverse.

Thus decisions about when, and by how much, to reallocate fish stocks from one sector to another, require considerable judgment backed up by analysis. Specifically, fishery managers need to have informed estimates of how quickly, and by how much, marginal net benefits for each sector are likely to change over time. That is they need to have a view as to what the future time path of allocation adjustment might look like. This can be the basis of an allocation strategy that can include design of appropriate institutional and regulatory structures to smooth the adjustment process.

In the absence of this forward looking strategic view of allocation there is a risk that sub-optimal resource allocation decisions will be made. The loss of economic benefits and social benefits in living with a sub-optimal resource stock allocation for one or more years can be significant.

Clearly then, fisheries management need an approach that will enable them to develop allocation strategies with the aim of optimizing long run social and economic benefits. Only by looking at allocation decisions in this way will fisheries management minimize the risk of making an allocation decision today that turns out to be sub-optimal and potentially very costly tomorrow.

However, for all the reasons given above, this approach cannot be based on frequent reapplication of the static model and adjustment of the allocations based on the results of the analysis at that time.

Rather it needs to be based on:

- a rigorous application of the static model to determine what the indicated current optimal allocation is and how far away from it the fishery is, and
- a method that allows the likely future time path of adjustment to be estimated.

Armed with both, a fisheries manager would be able to undertake appropriate analysis to determine what adjustments, if any, are needed to day and what is an appropriate future schedule of adjustments.

The reports coming from FRDC 2001/065 addressed the first dot point (application of the static model). This paper addresses the second. It develops an approach to the dynamic adjustment process that would allow fisheries management to take account of changes over time in the net benefit from commercial and recreational use of a fishery.

The model is based on identifying the key variables that affect commercial and recreational values over time, and the way they will change relative to each other over time. In this way it is based on capturing the key relationships that determine socially optimal stock allocations over time. The model also aims to facilitate scenario analysis of the way that future allocations are likely to be affected by changes in a range of key variables that affect the relative balance between recreational and commercial marginal net benefits. These include variables related to demography, biology, technical change including aquaculture developments, and underlying economic drivers and related market conditions. This will allow managers to understand the risks and uncertainties in setting an allocation strategy.

The dynamic model is not designed to specify precise optimal allocation solutions at future points in time in terms of exact quanta. Rather it will help fisheries managers and stakeholders to make informed stock re-allocation decisions today in the knowledge of the likely future trends in the relevant values relative to commercial and recreational fishing and the implications of the trends in these values for the likely direction of optimal stock allocation tomorrow.

An important outcome of dynamic modelling is that it will enable formulation of a smooth allocation path over time (with typically five to ten year timeframes) that is consistent with longer run economic, biological, demographic and other social trends shifting the relative benefits of commercial and recreational use through time. This will enable fisheries managers to take a more strategic approach to resource allocation issues by providing them with a practical interpretative tool that can forecast the direction of appropriate future fish stock allocations.

In developing the basic framework for analysing the path of likely adjustments over time, the logical starting point is to consider the relationships that lie behind the marginal net benefit schedules for commercial and recreational fishing. There are two parts to this. First, we need a framework for each marginal net benefit schedule that will enable us to understand and analyse the way that key variables influence changes in marginal net benefits. Second, we need a relatively straightforward framework or model that will allow us to calibrate the key relationships and shape of the time path of adjustment over time.

The first fits nicely within the demand and supply framework and its application to commercial and recreational activities are considered in the previous two sections. The second fits well with those models in economics which focus on relative growth rates for net benefits as part of benefit cost analysis of policy evaluation. This is considered in the next section.

## 5.3 Mathematical Model of Optimal Allocation Time Path

In order to develop a decision making approach to allocation in future periods we need to translate the thinking from the previous sections into a formulation of the optimal time path of allocation.

From any starting point there are in fact an infinitive number of allocation paths. Ideally we would to choose the one that maximized the value of the stream of benefits (the sum of commercial and recreational net benefits) over time. The economic approach to this is to maximize the net present value of this benefit stream as shown in the following equation.

$$NPV_{TP} = \sum_{i=1}^{i=n} \frac{B\,\mathrm{Re}c,i + BCom,i}{(1+r)^i}$$

.

If we maximize the NPV, subject to the absolute total allowable catch we will be selecting the optimal time path of allocation of the catch between the recreational and commercial sectors and maximizing the social value of the fishery. We know the sustainable catch to be allocated over time is given and we will assume that this is fixed. At any point in time the optimal allocation occurs where:

.

$$MNB\,\mathrm{Re}c,0 = MNBCom,0$$

Under this assumption no upfront adjustment is needed to the allocation. We just need to keep the equality in place over time by adjusting the allocation. To do this requires that we forecast the commercial and recreational marginal benefit value for each future year and solve for the allocation that equates the forecast recreational and commercial marginal benefits.

The previous static analysis has shown that a full evaluation of the marginal benefit functions is both data intensive and expensive. Hence, as have been argued previously we do not wish to be redo the full static exercise too frequently. However if we have the fully estimated base values an equation of the form;

$$B\,\mathrm{Re}c,i = B\,\mathrm{Re}c,_0(1 + X\,\mathrm{Re}c)^i$$

can be used to project recreation benefits and an equation of the form;

$$BCom,i = BCom,_0(1 + XCom)^i$$

can be used to project the level commercial benefits.

If total catch is set at Q. then;

$$Q\mathrm{Re}c + QCom = Q$$

and we can consider how the marginal benefits change over time through the Xrec and XCom growth factors and through the feedback effect of changes in Qrec and Qcom on the marginal benefits of recreational and commercial fishing activity.

Assume linear demand for recreational and commercial fishing. Then the process of adjusting over two periods is as show in the following diagrams.

Clearly, if in the above equations, XRec > XCom fish continue to allocate to recreational activities Yet, at any time in the future when we reallocate to recreational use and away from commercial use, the marginal benefit to commercial use rises and the marginal benefit to recreational fishing declines.

We need to solve for this change. This is done below.

Let the marginal benefit curves be linear so that:

$$MB\,\mathrm{Re}c = \alpha_{rec} - \beta_{rec}Q_{rec}$$
$$MBCom = \alpha_{com} - \beta_{com}Q_{com}$$

Looking at a reallocation the effect is the change in Qcom and in Qrec such that;

$$-dQcom = dQrec$$

and the marginal benefits change according to;

$$dMB_{com} = -\beta_{com}dQ_{com}$$
$$dMB_{rec} = -\beta_{rec}dQ_{rec}$$

In applying this model we have in effect two steps.

Starting from base period zero (today) and moving to period 1 pre allocation change we have;

$$MB_{com}{}^{1} = MB_{com}{}^{0}(1 + X_{com})^{1}$$
$$MB_{rec}{}^{1} = MB_{rec}{}^{0}(1 + X_{rec})^{1}$$

Post reallocation based on the comparison between these two we would have;

$$MB_{com}{}^{1} = MB_{com}{}^{0}(1 + X_{com})^{1} - \beta_{com}dQ_{com}$$
$$MB_{rec}{}^{1} = MB_{rec}{}^{0}(1 + X_{rec})^{1} - \beta_{rec}dQ_{rec}$$

These equations cane be solved for the exact allocation adjustment required in period 1 to optimize the allocation.

To do this we need to recognize that if a full static analysis has been done as the starting point we already know:

$$MBcom^0, MBrec^0, Qcom^0, Qrec^0, Q = Qcom^0 + Qrec^0$$

as well as the shape (functional form) of the best fitting marginal benefit schedule. We are assuming linear functions for exposition here.[8]

In addition following the approach outlined in previous sections we can encapsulate the various key drivers into the estimates of the growth terms;

$$Xrec, Xcom \quad (0.1)$$

This allows a solution using;

$$MB_{com}{}^1 = MB_{com}{}^0 (1 + X_{com})^1 - \beta_{com} dQ_{com} = MB_{rec}{}^1 = MB_{rec}{}^0 (1 + X_{rec})^1 - \beta_{rec} dQ_{rec}$$

The solution can either be based on the view that

$$MBcom^0 = MBrec^0$$

meaning that we start from an initial optimal allocation or the view that;

$$MBcom^0 \neq MBrec^0$$

meaning that we start from an initial sub optimal allocation. Whichever is appropriate will depend on the results of the upfront full static analysis and an assessment of how close the starting point is to the static allocation optimum.

Taking the equality view we can solve for the optimal time path of allocation as follows;

[8] The actual functional form will be determined by the recreation and commercial analysis. In the case studies in Parts 2, 3 and 4 of this project, the recreational marginal benefit function was derived from contingent valuation surveys of fishers in each fishery while the commercial marginal benefit function was derived from revenue and cost data from fishers in each fishery.

$$MB_{com}{}^{0}(1+X_{com})^{1}-\beta_{com}dQ_{com}=MB_{rec}{}^{0}(1+X_{rec})^{1}-\beta_{rec}dQ_{rec}$$

which setting

$$MB_{com}{}^{0}=MB_{rec}{}^{0}$$

becomes

$$MB_{com}{}^{0}(1+X_{com})^{1}-MB_{com}{}^{0}(1+X_{rec})^{1}=\beta_{com}dQ_{com}-\beta_{rec}dQ_{rec}$$

and because total allowable catch is fixed and

$$dQ_{rec}=-dQ_{com}$$

becomes

$$MB_{com}{}^{0}(1+X_{com})^{1}-MB_{com}{}^{0}(1+X_{rec})^{1}=\beta_{com}dQ_{com}+\beta_{rec}dQ_{com}$$

or

$$MB_{com}{}^{0}(X_{com}-X_{rec})=(\beta_{com}+\beta_{rec})dQ_{com}$$

so that the required adjustment is;

$$dQ_{com}=MB_{com}{}^{0}(X_{com}-X_{rec})/(\beta_{com}+\beta_{rec})$$

$$dQ_{rec}=-dQ_{com}$$

These equations allow us to project the optimal allocation in a spreadsheet optimization model using simple approaches like “goal seek” or more sophisticated “solver” type models if there are side constraints such as maximum actual reallocations allowed in any one period.

The marginal benefit functions for a fishery will be specific to that fishery and will generally be non linear. The exact functional form and associated coefficient estimates will be an outcome of the detailed static analysis of the kind applied in the previous study by McLeod and Nicholls of the crab, abalone and wetline fisheries in Western Australia.

Taking the linear functions as illustrative the application will produce results such as those illustrated in Figure 28, Figure 29 and Figure 30 below.

**Basic Data Sheet**

| | Assumptions | |
|---|---|---|
| Annual Growth Rate in Recreational Net Benefits | X*rec* | 0.07 |
| Annual Growth Rate in Commercial Net Benefits | X*com* | 0.03 |
| Marginal Net Benefit Recreational Catch Base Year | MB *rec,0* | |
| Marginal Net Benefit Commercial Catch Base Year | MB *com,0* | |
| Fish Stock to Be Allocated | Q | 1000 |
| Intial Recreational Allocation | Q *rec*, 0 | 400 |
| Initial Commercial Allocation | Q *com,0* | 600 |
| Marginal Benefit Functions From Base Year Estimation | | |
| Recreational MB fucntion constant | $\alpha_{rec}$ | 15 |
| Commercial MB function constant | $\alpha_{com}$ | 30 |
| Recreational MB fucntion slope | $\beta_{rec}$ | 0.01 |
| Commercial MB function slope | $\beta_{com}$ | 0.02 |

**Figure 28: Illustrative Data Sheet For Time Path Model**

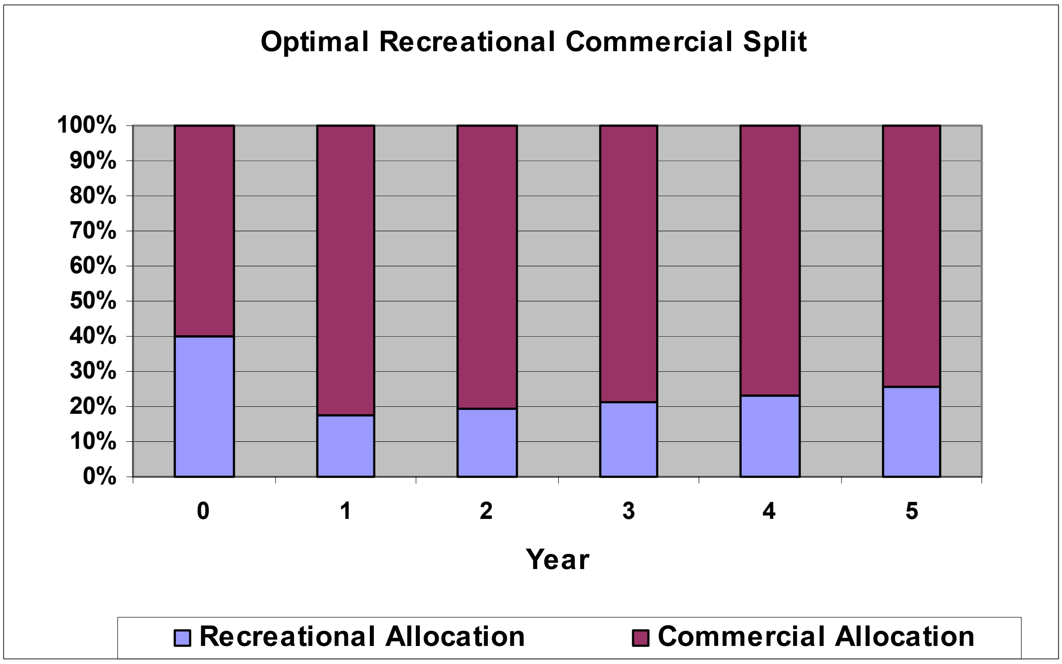


**Figure 29: Illustrative Time Path of Allocation for Data Sheet Assumptions**

**Calculation of Optimal Time Path of Allocation**

| Year | 0 | Year 1 | | Year 2 | | Year 3 | | Year 4 | | Year 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj |
| Total Allowable Catch, Q | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Recreation Allocation, Qrec | 400 | 400 | 174 | 174 | 193 | 193 | 213 | 213 | 234 | 234 | 256 |
| Commercial Allocation, Qcom | 600 | 600 | 826 | 826 | 807 | 807 | 787 | 787 | 766 | 766 | 744 |
| Marginal Net Benefit Recreation - MBrec,t | 11 | 12 | 14.03 | 15 | 14.82 | 16 | 15.66 | 17 | 16.55 | 18 | 17.49 |
| Marginal Net Benefit Commercial - MBcom,t | 18 | 19 | 14.03 | 14 | 14.82 | 15 | 15.66 | 16 | 16.55 | 17 | 17.49 |
| Difference in Marginal Net Benefit (MBrec,t-MBcon,t) | -7 | -7 | 0.00 | 0.56 | 0.00 | 0.59 | 0.00 | 0.63 | 0.00 | 0.66 | 0.00 |
| Change in commercial allocation required to optimize allocation, year t | | | 226 | | -18.70 | | -19.76 | | -20.88 | | -22.07 |

**Figure 30: Illustrative Worksheet for Optimal Time Path of Allocation Showing Annual Adjustments**

# 6 Estimating the Magnitude of the Key Growth Variables XRec and XCom

The key growth factors XRec and XCom are used in conjunction values of marginal benefits to solve for the optimal allocation. As much as possible, and to be consistent with the analysis of the underlying economics of commercial and recreational fishing as presented in previous sections we need to have similar variables underlying the estimates of both XRec and XCom. We consider XCom first and then XRec.

## 6.1 Overall Impact of Demand and Supply Shifts on Commercial Net Benefits and Estimated Value for XCom

Changes are continuously taking place in the key underlying drivers of both supply and demand that will impact over time on the commercial marginal net benefit estimates determined from the application of the static model. Using the model set out above provides a helicopter' or macro view of those key drivers that will be in play to impact on the likely future direction of shifts in these schedules and of the likely impact that these changes will have on the direction and rate of changes to commercial marginal net benefits into the foreseeable future. The conceptual framework is not about tracking down all drivers to establish a finite view of what those values might be in the future.

$$MB_{com}{}^{t} = MB_{com}{}^{0}(1 + X_{com})^{t}$$

Where: $MBcom^t$ is the commercial marginal net benefit in the future time period t.

$MBcom^0$ is the commercial marginal net benefits determined from the application of the static model specified in previous research by McLeod and Nicholls[9]. This sets the values for the base period, period 0.

XCom is the percentage annual growth in the benefits; that is the expected annual growth in MBCom.

In estimating XCom we need to incorporate the various drivers of commercial value identified in Sections3 and 4 expressed as annual percentage growth rates. In the simplest formulation we could expect XCom to be a function of:

[9] op cit 2

- annual population growth. In Western Australia this is around 1.5% per annum.
- annual change in demand for fish because of any expected fundamental shift in taste or preferences of local consumers.
- annual growth in real incomer per capita. In Western Australia this is about 2.5% per annum.
- the income elasticity of local (or export) demand in consumers' (local or export markets) consumption of the specific fish species. Based on major UK studies the income elasticity of demand for fresh fish is around 0.3. This income elasticity determines the impact of increase in real income per capita on fish demand. If the annual real income growth is say 2.5% and the income elasticity of demand for fresh fish specie were 0.30, then the real income growth impact on the demand for that fish would shift the demand outward at an annual rate of 0.75% (2.5%x 0.30).
- annual percentage change in the underlying real local prices of alternative meats for fish multiplied by the cross elasticity of substitution of alternative meats in consumers' fish consumption. If prices of alternative meats fall relative to fish, then consumers will shift towards these meats and away from fish. The cross elasticity measures the extent to which consumers are strongly committed to fish and are not influenced by given changes in the price of other meats relative to fish. Based on the major UK studies, the cross elasticity of demand for fish is around 0.25. Therefore, if, for example, underlying real prices of alternative meats is declining at an annual rate of say 3% and the cross elasticity of substitution of these meats for fish were 0.25, then alternative meat substitution impact on the demand for fish would be a negative shift of – 0.75% annually (3% x 0.25).
- annual percentage change in production costs adjusted for the annual percentage gain in productivity, i.e. if harvest and post harvest production costs at the margin are increasing at an annual rate of 3% and productivity gains are running at 5%, then the net impact is downward shift in supply curve at an annual rate of 2%. This net gain will be reflected in increased producers surplus for an output controlled fishery but in the case of an input-controlled fishery the productivity gain could be assumed to be consumed by management rule changes in the fishery to prevent catch exceeding sustainable levels due to net gains from 'technology creep'. In the reverse situation, where the annual percentage productivity gains are less than the annual percentage increase in production costs at the margin, then this will impact negatively on producer surplus and the

aggregate commercial net benefit from commercial use for a fishery under either output or input controlled management regime. If the situation in the above example were reversed, then there would be upward shift in the supply schedule to reflect the increased net costs after adjustment for productivity gain of 2%.

## 6.2 Overall Impact of Demand and Supply Shifts on Commercial Net Benefits and Estimated Value for XRec

For recreational fishing we are looking to estimate

$$MB_{rec}{}^{t} = MB_{rec}{}^{0}(1 + X_{rec})^{t}$$

Where: $MBrec^t$ is the recreational marginal net benefit in the future time period t.

$MBrec^0$ is the recreational marginal net benefits determined from the application of the static model specified in previous research by McLeod and Nicholls[10]. This sets the values for the base period, period 0.

XRec is the percentage annual growth in the benefits; that is the expected annual growth in MBRec.

In estimating XRec we need to incorporate the various drivers of commercial value identified in sections 3 and 4 expressed as annual percentage growth rates. In the simplest formulation we could expect XRec to be a function of:

- annual population growth. In Western Australia this is around 1.5% per annum.
- annual change in demand for recreational fishing because of changes or fundamental shifts in taste or preferences of local recreational fishers and current non fishers towards or away from recreational fishing. This will show up as a change in the participation rate.
- change in the demographic composition of the population over time. For recreational fishing, participation rates and type of fishing appear to vary with age.
- annual growth in real incomer per capita. In Western Australia this is about 2.5% per annum.

[10] op cit 2

- the income elasticity of demand for recreational fishing. Many studies find recreational pursuits to be income elastic.
- annual percentage change in the underlying real local prices of alternative recreational activities and the cross elasticity of substitution between these alternatives and recreational fishing. If prices of alternative activities fall relative to the "price" of local fishing then consumers will shift towards these activities and away from local recreational fishing.

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ECONOMIC RESEARCH ASSOCIATES

# DYNAMIC MODELLING OF THE SOCIALLY OPTIMAL ALLOCATION OF FISH RESOURCES BETWEEN COMMERCIAL AND RECREATIONAL USE

## (FRDC Project 2003/039)

## PART TWO

## COCKBURN SOUND CRAB FISHERY CASE STUDY

**By R Lindner, P McLeod and J Nicholls**

# FOREWORD

The Cockburn Sound Crab Fishery is one of three case studies used to calibrate the socially optimizing dynamic model for evaluating allocation options for fish stocks between recreational and commercial fishing. This was outlined in Part A of this research project.

This project builds on previous FRDC-funded research by Hundloe, *et al* and by McLeod and Nicholls. The later research (FRDC project 2001/065) provided fisheries managers and stakeholders with a framework and methodology to estimate and compare marginal values of fish caught by the commercial and recreational sectors on a sound and consistent basis.

The case studies fisheries are the same as those used by McLeod and Nicholls in their previous research to demonstrate the application of the general theoretical framework and methodologies for a single period, static, model outlined in that previous research. The other two are the Perth Abalone fishery and the West Coast 'wetline' fishery.

This Cockburn Sound Crab Fishery case study uses and builds on the methodology and information discovered and described in that earlier research.

As a result of this and the earlier research mentioned above, fisheries managers and stakeholders have access:

- To a clear explanation of the appropriate conceptual framework for resource allocation decisions; and
- To sound and consistent guidelines for applying suitable tools to estimate comparable values for evaluating resource allocation between competing uses and for determining the socially optimal allocation path for fish stock.

Whilst this research focused on recreational and commercial uses, the conceptual framework and valuation methodologies and tools are capable of being applied to evaluate a wider set of allocation options (passive and non-passive) for a fish stock on a sound and consistent basis.

**Economic Research Associates**

**August 2006**

**CONTENT**

## TABLES AND FIGURES

# 1. INTRODUCTION

## 1.1 Background

The Cockburn Sound Crab fishery is one of three case studies designed to provide practical guidance to fisheries management and stakeholders in the application of the general theoretical framework and dynamic modelling tool to address the socially optimal allocation path of fish stocks between the commercial and recreational fishing sectors.

Earlier research by McLeod and Nicholls[1] provided a conceptual framework and methodological tools for estimating the appropriate marginal values for recreational and commercial fishing at a point in time on a sound and consistent basis and for determining the socially optimal allocation at that point in time. This was applied to the Cockburn Sound Crab fishery as one three case studies used to demonstrate the application of this theoretical framework and static modelling tool.

The Cockburn Sound Crab fishery case study results provided a benchmark of the marginal values of commercial and recreational use and socially optimal allocation in the fishery at a point in time. However, whilst it is critical to identify socially optimal allocations at a given point in time, it is equally important to recognize that this optimal allocation is likely to change over time.

The results from the previous static analysis determinants of fish stock highlighted the need to understand not just the marginal values that commercial and recreational uses generate for fish stocks but how these values are likely to change over time, the underlying determinants of these changes in relative values and how these changes impact on the future optimal allocation.

Whilst the static analysis gives fisheries management a well defined framework for comparative assessing allocation at a point in time, decision makers around Australia considered that there would be value in further analysis that looked at a dynamic model capable of modelling the impact of changes in key drivers on commercial and recreational relative values over time, and on consequential changes in the socially optimum allocation through time.

[1] McLeod , P and Nicholls, J . 'A Socio-Economic Valuation of Resource Allocation Options between Commercial and Recreational Sectors: Part II The Western Australian Cockburn Sound Crab Fishery Case Study' FRDC Project 2001/065. FRDC: Canberra. 2004.

The basic theory of the dynamic analysis was developed in Lindner, McLeod and Nicholls[2]. The current study develops a dynamic model that can be used to consider the way that relative marginal values may change over time and how this may affect the optimal resource allocation for the Cockburn Sound Crab fishery.

## 1.2 The Report Structure

Chapter 2 briefly looks at the fishery and revisits the outcomes from the application of the basic static allocation model to the Cockburn Sound Crab fishery. It describes what is needed to develop the dynamic allocation model for the fishery. Chapter 3 looks at the marginal net benefit from commercial catch and the key drivers that cause the marginal commercial value to change over time. Chapter 4 looks at the marginal net benefits from recreational catch and the key drivers that change these marginal net benefits over time. Chapter 5 puts these into a dynamic framework that allows the direction of the change in the socially optimum allocation of crab through time to be estimated. Finally, Chapter 6 looks at the policy implications of the socially optimum allocation path results from the application of the dynamic model.

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[2] Lindner, R, McLeod, P and Nicholls, J. Dynamic Modelling of Socially Optimal Resource Allocation,. Part A, A General Theoretical Framework. FRDC Project 2003/039. FRDC: Canberra. 2005

# 2 Overview of Cockburn Sound Crab Fishery, Static and Dynamic Allocation Models

## 2.1 Management Regime in the Cockburn Sound Crab Fishery

This small embayment fishery near Fremantle in Western Australia is not subject to any explicit total allowable catch controls. The limited-entry commercial fishery is controlled by a suite of input (pot numbers), biological and seasonal controls. On the recreational side, daily catch limits apply along with gear and biological controls.

The legal minimum sizes of crab that can be taken from the fishery differ slightly between the two sectors (130mm carapace width in the case of commercial take and 127mm for recreational fishers). This means the stock being allocated are not entirely identical.

The reported annual commercial catch was estimated at 212 tonnes at the time of the earlier research by McLeod and Nicholls[3], whilst results of a more recent recreational survey that have been published since that earlier research suggests that the recreational take was likely to be closer to 18 tonnes in the same year as the commercial catch data.

## 2.2 Original Static Model Results

The previous study by McLeod and Nicholls estimated the marginal net benefit from commercial and recreational use on the assumption that existing effort and catch in the Cockburn Sound Crab fishery is sustainable. The results of that analysis are shown in Figure 1 below.

[3] op cit 1

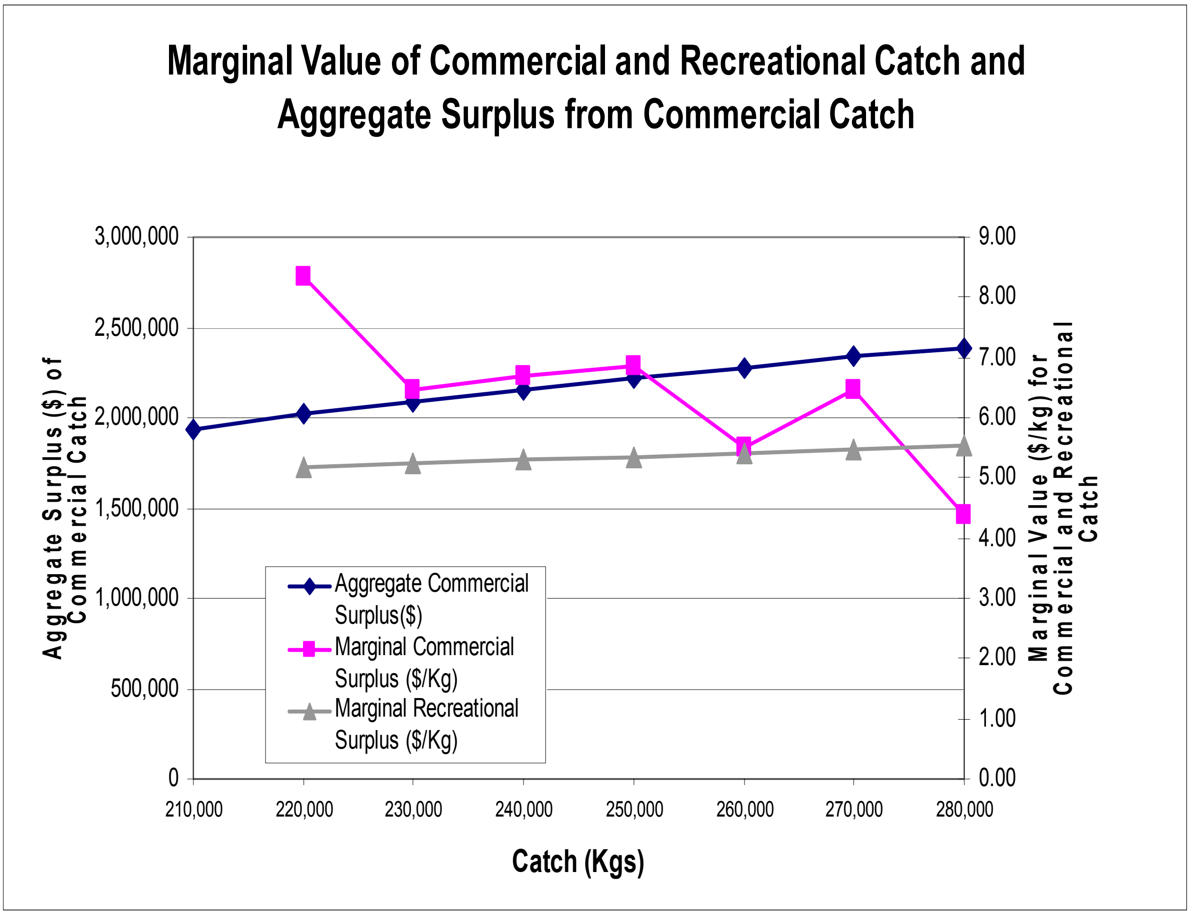


**Figure 1: Marginal Net Benefits of Commercial and Recreational Use and Aggregate Consumer Surpluses in the Cockburn Sound Crab Fishery**

The commercial net benefits are derived from consumer surpluses (as around 55 per cent of that crab catch was consumed locally) and from producer surpluses for the harvesting and processing of the commercial catch for domestic and export markets.

On the recreational side, the survey data available indicated that use value dominated and that experiential (and other) values typically associated with recreational fishing were not significant in the Cockburn Sound crab fishery.

The relationship between the marginal benefit from commercial and recreational use varies with catch level. This reflects the underlying demand and supply conditions on the commercial side and the underlying preferences on the recreation side.

At low catch level, such as those that have been achieved recently, the marginal net benefits from commercial use were estimated to be higher than the marginal net benefits from recreational use. If additional crabs were to become available for allocation, proportionally more would need to be allocated to commercial use (about two thirds) than to recreational use (about one third) in order to optimize overall net benefits from the combined commercial and recreational uses.

However, proportionally more of any increased availability of crab would need to be allocated to recreational use as catches approach 260 tonne, the point at which marginal benefits of commercial and recreational use are estimated to be the same.

The static analysis revealed that any additional crab available for allocation beyond around 250-260 tonne would need to be allocated entirely for recreational use. This is because industry (combined harvest and post harvest activities) were estimated to be in a situation of marginal loss when commercial catches exceed 250 tonne. That is, industry's estimated marginal costs exceed its marginal revenue. This decline in 'producer surpluses' is not off set by the increase in retail consumer surpluses at lower prices due to the increased supply of Cockburn Sound crabs with increased catch entering the local markets.

It was noted in the earlier research that one of the issues in applying the static, single period, framework was the absence of a definitive aggregate catch figure. Applying the above logic allows an indication of the appropriate allocations without this. For example, if the total sustainable catch was estimated to be 400 tonnes, the split would be approximately 250 tonnes commercial and 150 tonnes recreational.

Of course, these results are illustrative only and a 'snapshot' in time. The outcomes are dependent on the robustness of the assumptions behind the modeling.

## Underlying Assumptions for Applying Optimal Resource Sharing Models

This previous analysis of the Cockburn Sound crab fishery was based on the following assumptions:

- The combined existing commercial and recreational catch is all that is sustainable and available for inter-sectoral allocation, but this is ambiguous under the existing management regime;
- All recreational participants are subject to binding constraints (bag limits), that is, there is no unused or spare capacity, but the survey results at that time showed that this was not the case for some recreational fishers in the Cockburn Sound crab fishery;
- All commercial operators are internally structured to maximize producer surpluses from Cockburn Sound crab catches, and, given the scope to restructure through the transfer of unit pot entitlement among commercial licensees, this is most likely the case in the harvesting sector; and
- The fish stock to be shared between commercial and recreational sectors are the same, but there was some ambiguity in terms of the stock being fished given the differences in the minimum size of the crab that can be taken by recreational and commercial fishers.

However, for the purposes of applying the dynamic model, these limiting factors are assumed to be not present.

## 2.3 Applying the Dynamic Model to Cockburn Sound Crab

The starting point for the application of the dynamic model is the dynamic framework developed in Lindner, McLeod and Nicholls[4] and the static model marginal values and optimal allocation results from the previous study by McLeod and Nicholls[5].

In essence, we have to take the marginal net benefit functions as shown in Figure 1 and fit them into the dynamic framework shown in Figure 2 and Figure 3 below.

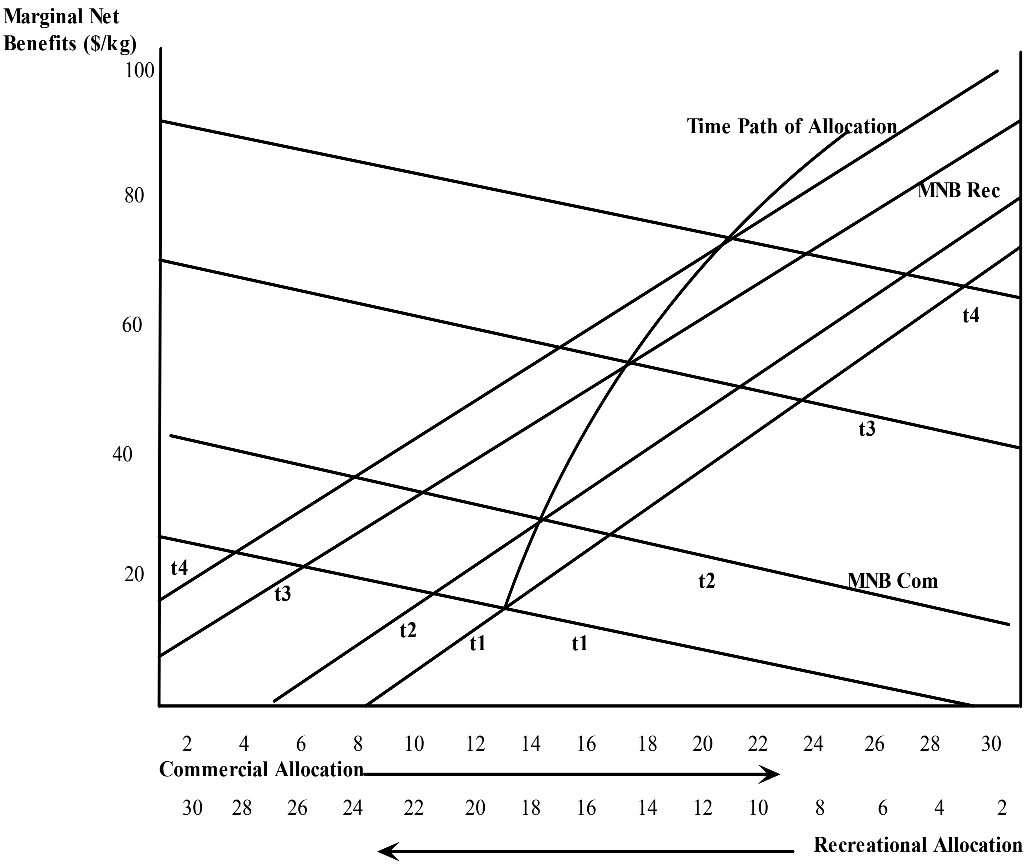


**Figure 2: Optimal Time Path of Allocation When Shift is Toward Commercial Use of the Cockburn Sound Crab Fishery**

[4] op cit 2

[5] op cit 1

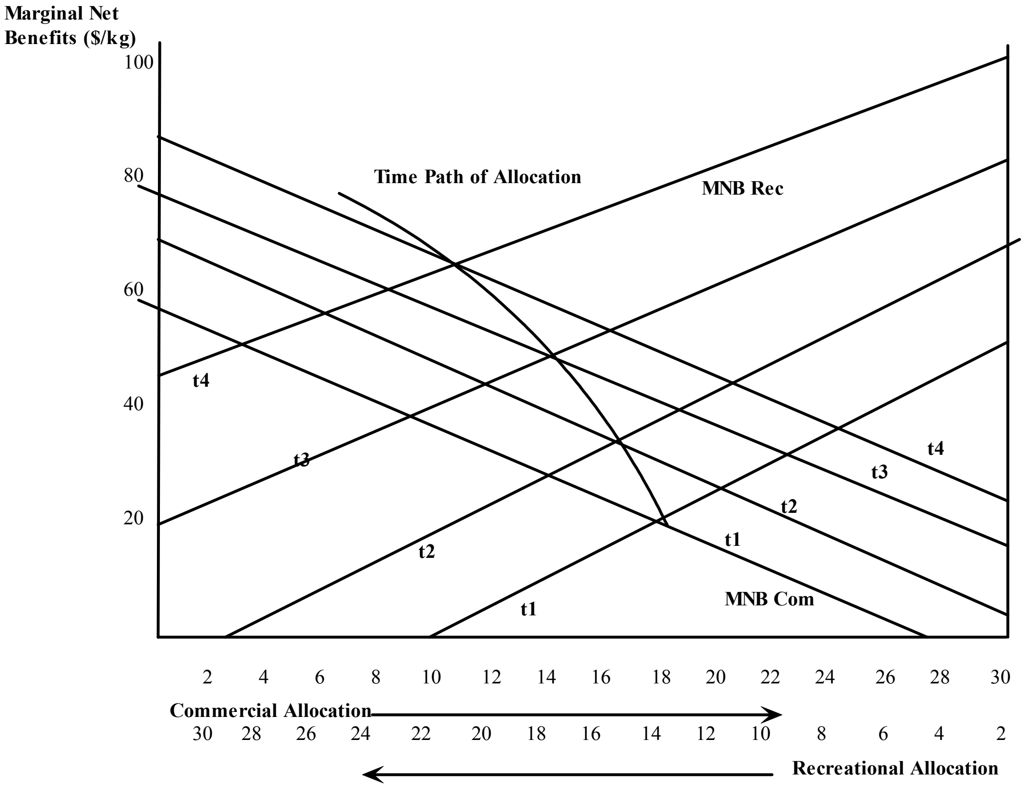


**Figure 3: Optimal Time Path of Allocation When Shift is Toward the Recreational Use of the Cockburn Sound Crab Fishery**

In Figure 2 the optimal allocation moves toward the commercial sector over the four time periods t1 to t4. In Figure 3 the optimal allocation moves toward the recreational sector in each of the four time periods.

These diagrams assume that we start from the optimal initial allocation such as that shown for the fishery in Figure 1 above. However, in Figure 1, the optimal allocation requires an adjustment toward commercial use to achieve an initial optimal allocation at the existing catch levels. The existing allocation was therefore sub-optimal in the current environment and the dynamic model needs to cope with this.

The application of the dynamic model is based on identifying the key variables that affect commercial and recreational values over time, and the way they will change relative to each other over time. That is, it is based on formulating relationships that determine how the commercial and recreational marginal valuation schedules shown in Figure 2 and Figure 3 change over time.

The variables that will shift these relationships include demography, biology, technical change (including aquaculture developments), and underlying economic drivers and related market conditions.

The dynamic model is not designed to specify precise optimal allocation solutions at future points in time in terms of exact quanta for the Cockburn Sound crab fishery.

Rather it will help fisheries managers and stakeholders to make informed stock re-allocation decisions today in the knowledge of the likely future trends in the relevant values relative to commercial and recreational fishing for crab and the implications of the trends in these values for the likely direction of optimal stock allocation of crab tomorrow. The analysis is based on the notion of a total allowable catch that will be in existence over time and which is to be allocated optimally between the commercial and recreational sectors in a zero sum game framework

An important outcome of dynamic modelling is that it will enable formulation of a smooth allocation path over time (with typically five to ten year timeframes) that is consistent with longer run economic, biological, demographic and other social trends shifting the relative benefits of commercial and recreational use through time. This will enable fisheries managers to take a more strategic approach to resource allocation for Cockburn Sound crab by providing them with a practical interpretative tool that can forecast the direction of appropriate future fish stock allocations.

## 2.4 The Dynamic Model for Cockburn Sound Crab

In developing the basic framework for analysing the path of likely allocation adjustments over time, the logical starting point is to consider the relationships that lie behind the marginal net benefit schedules for commercial and recreational fishing. There are two parts to this. First, we need a framework for each marginal net benefit schedule that will enable us to understand and analyse the way that key variables influence changes in marginal net benefits. Second, we need a relatively straightforward framework or model that will allow us to calibrate the key relationships and shape of the time path of allocation adjustment over time.

The first fits neatly within the conventional demand and supply framework and the drivers are variables that shift the relevant demand and supply curves. The second matches well with those policy evaluation models in economics, which focus on relative growth rates for net benefits as part of benefit cost analysis. This is the approach that is considered in the next section.

## 2.5 Mathematical Model of Optimal Allocation Time Path for Cockburn Sound Crab

In order to develop a decision making approach to allocation in future periods we need to translate the thinking from the previous sections into a formulation of the optimal time path of allocation. The starting point is the static model and associated optimal allocation and marginal values as reflected in Figure 1.

For Cockburn Sound Crab, the commercial marginal net benefit is a diminishing function of catch. That is, the marginal net commercial benefit per kg reduces as the quantum of Cockburn Sound crab allocated to commercial use increases.[6] The analysis was based on surveys of catching and retail activities.

The recreational marginal net benefit schedule is derived from the logistic choice model that was estimated in McLeod and Nicholls[7]. This was based on a contingent survey of Cockburn Sound crab fishers, which focused on their marginal willingness to pay for additional daily bag limits.

From any starting point there are in fact an infinite number of allocation paths. Ideally we would choose the one that maximized the value of the stream of benefits (the sum of commercial and recreational net benefits) over time. The economic approach to this is to maximize the net present value of this benefit stream as shown in the following equation.

$$NPV_{TP} = \sum_{i=1}^{i=n} \frac{Brec,i + Bcom,i}{(1+r)^i}$$

If we maximize the NPV, subject to the absolute total allowable catch we will be selecting the optimal time path of allocation of the catch between the recreational and commercial sectors and maximizing the social value of the fishery. We assume the sustainable catch to be allocated over time is as mentioned above and that this is fixed for the purposes of applying the dynamic modelling. At any point in time the optimal allocation occurs where:

.

$$MNBrec = MNBcom$$

Under this assumption no upfront adjustment is needed to the allocation. We just need to keep the equality in place over time by adjusting the allocation. To do this requires that we forecast the commercial and recreational marginal benefit value for each future year and solve for the allocation that equates the forecast recreational and commercial marginal benefits.

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[6] The marginal commercial net benefit captures both consumer surplus and producer surplus associated with commercial harvest and consumption.

[7] op cit 1

Based on the general dynamic model developed in Lindner, McLeod and Nicholls[8], we begin with the fully documented base values for Cockburn Sound crab for both commercial and recreational use.

For the recreational sector the base value is assumed to grow (decline) according to the relationship:

$$Brec,i = Brec,_0(1+Xrec)^i$$

For the commercial sector the base value is assumed to grow (decline) according to the relationship:

$$Bcom,i = Bcom,_0(1+Xcom)^i$$

If total allowable catch for Cockburn Sound crab is set at Q. then:

$$Qrec + Qcom = Q$$

and we can consider how the marginal benefits change over time through the X*rec* and X*com* growth factors.

If the X*rec* and c*Com* factors vary in a systematic way over time, we will get a systematic affect on the optimal allocation. For example, if X*com*<X*rec*, then over time the marginal benefit of recreational use grows relative to commercial use and optimal allocation moves in the direction of the recreational sector.

This is not enough to achieve equilibrium short of the entire stock going ultimately to one sector. We need to have a feedback mechanism whereby, as stock is allocated to a sector, the marginal benefit is reduced for further additional allocation. That is, there is a feedback effect of changes in Q*rec* and Q*com* on the marginal benefits of recreational and commercial fishing activity after a stock re-allocation adjustment.

Based on Figure 1 and reflecting the study of commercial crab in McLeod and Nicholls[9], the marginal benefit for commercial use of Cockburn Sound crab is diminishing value. Using a linear form we get:

$$MB_{Com} = \gamma_{com} - \alpha_{com} Q_{com}$$

$\gamma_{com}$ is a constant and $\alpha_{com}$ is the coefficient derived from a linear regression fitted to the marginal commercial benefit data shown in Figure 1.

[8] op cit 2

[9] op cit 1

The marginal benefit for recreational use is based on the contingent valuation model results for recreational crab fishers in McLeod and Nicholls[10]. The best fitting equation was a linear specification (see below) which means that:

$$MB_{\mathrm{Re}\,c} = \alpha_{rec} / \beta_{rec}$$

The values for $\alpha_{rec}$ and $\beta_{rec}$ are the values from the estimated logistic choice model.

Looking at a re-allocation the effect is to change Q*com* and Q*rec* such that:

$$-dQcom = dQrec$$

and the marginal benefits change according to:

$$dMB_{com} = -\alpha_{com}.dQ_{com}$$

And

$$dMB_{rec} = 0.dQ_{rec}$$

In applying this model we have in effect two steps.

Starting from base period zero (today) and moving to period 1 pre allocation change we have:

$$MB_{com}{}^{1} = MB_{com}{}^{0}(1 + X_{com})^{1}$$
$$MB_{rec}{}^{1} = MB_{rec}{}^{0}(1 + X_{rec})^{1}$$

Post reallocation based on the comparison between these two we would have:

$$MB_{com}{}^{1} = MB_{com}{}^{0}(1 + X_{com})^{1} - \alpha_{com} dQ_{com}$$

And

$$MB_{rec}{}^{1} = MB_{rec}{}^{0}(1 + X_{rec})^{1} + 0.dQ_{rec}$$

These equations can be solved for the exact allocation adjustment required in period 1 to optimize the allocation.

To do this we need to recognize that, if a full static analysis has been done as the starting point, we already know:

$$MBcom^{0}, MBrec^{0}, Qcom^{0}, Qrec^{0}, Q = Qcom^{0} + Qrec^{0}$$

as well as the shape (functional form) of the best fitting marginal benefit schedules.

[10] op cit 1

For the analysis of the allocation of Cockburn Sound crab, the values of these variables is as derived in the previous static analysis of the Cockburn Sound Crab fishery.

In addition following the approach developed in the theoretical framework we can encapsulate the various key drivers into the estimates of the growth terms:

$$Xrec, Xcom$$

This allows a solution using:

$$MB_{com}{}^{1} = MB_{com}{}^{0}(1 + X_{com})^{1} - \alpha_{com} dQ_{com} = MB_{rec}{}^{1} = MB_{rec}{}^{0}(1 + X_{rec})^{1} + 0.dQ_{rec})$$

The solution can either be based on the view that

$$MBcom^{0} = MBrec^{0}$$

meaning that we start from an initial optimal allocation or the view that:

$$MBcom^{0} \neq MBrec^{0}$$

meaning that we start from an initial sub optimal allocation.

Whichever is appropriate will depend on the results of the upfront full static analysis and an assessment of how close the starting point is to the static allocation optimum. In the case of Cockburn Sound crab, as shown in Figure 1, the initial starting point is not a static optimum and in fact

$$MBcom^{0} < MBrec^{0}$$

This implies that the initial adjustment toward optimal allocation should be toward greater recreational use for Cockburn Sound crab in period 0.

Taking the equality view we can solve for the optimal time path of allocation as follows;

$$MB_{com}{}^{0}(1 + X_{com})^{1} + \frac{\partial MB_{com}}{\partial Q_{com}} dQ_{com} = MB_{rec}{}^{0}(1 + X_{rec})^{1} + \frac{\partial MB_{rec}}{\partial Q_{rec}} dQ_{rec}$$

Based on the analysis presented above,

$$\partial MB_{com} / \partial Q_{com} = -\alpha_{com}\text{, and}$$

$$\partial MB_{rec} / \partial Q_{rec} = 0$$

Substituting we get;

$$MB_{com}{}^{0}(1+X_{com})^{1}-\alpha_{com}dQ_{com}=MB_{rec}{}^{0}(1+X_{rec})^{1}$$

Solving for $dQcom$ we get;

$$dQ_{com}=(MB_{rec}{}^{0}(1+X_{rec})^{1}-MB_{com}{}^{0}(1+X_{com})^{1})/-\lambda_{com}$$

To get $dQ_{rec}$ we can use the fact that;

$$dQ_{rec}=-dQ_{com}$$

These equations allow us to project the optimal allocation in a spreadsheet optimization model for the allocation of Cockburn Sound crab using simple approaches like "goal seek" or more sophisticated "solver" type models if there are side constraints such as maximum actual reallocations allowed in any one period.

The marginal benefit functions in the current study and used above are specific to the Cockburn Sound crab fishery.

The exact functional forms have been chosen based on the detailed static analysis of the Cockburn Sound crab fishery in the previous study by McLeod and Nicholls[11]. The coefficient estimates needed to "calibrate" the model also come from this study.

## 2.6 Calibrating the Model

To solve the model using the above equations requires that we have estimates for:

- All base level parameters and variables, namely $MBcom^{0}, MBrec^{0}, Qcom^{0}, Qrec^{0}$, and $Q=Qcom^{0}+Qrec^{0}$
- The key growth rate variables namely X*rec* and X*com*.

The first set of values come directly from the static allocation analysis, while the second are new and must be estimated. The estimation of X*com* is taken up in Chapter 3 and X*rec* is considered in Chapter 4.

[11] op cit 1

# 3 Drivers of the Commercial Marginal Net Benefit Values – Finding X*com* For Cockburn Sound Crab

## 3.1 Background

Historically, the commercial catch in this fishery fluctuates from year to year. As mentioned in the earlier McLeod and Nicholls report[12], at a commercial catch of 212 tonnes, around 55 per cent was consumed domestically either as whole green or cooked crab, whilst the remaining 45 per cent was either exported (30 per cent) to fish markets in the Eastern States (Melbourne or Sydney) or processed locally to exact crab meat.

The Eastern States markets tend to be residual markets for Cockburn Sound crab supplies that are surplus of local demand. Consequently, the exported proportion of the Cockburn Sound crab catch can vary from year to year depending on the size of the catch and extent of alternative crab supplies available on local markets in Western Australia.

## 3.2 Local Demand Drivers

Local market demand for Cockburn Sound crab will be driven largely by population growth, rising real per capita incomes, and shifting product preferences. These key drivers of local demand for crab are shown in Table 1 below.

**Table 1: Key Drivers of Local Demand for Cockburn Sound Crab**

| Key Local Demand Drivers | Annual Rate of Growth (%) |
|---|---|
| Population Growth | 1.40 |
| Real Per Capita Income Growth | 0.70[1] |
| Total | 2.10 |

Notes: [1]Real per capita income growth multiplied by an estimated income elasticity of demand of 0.30

Source: Australian Bureau of Statistics

Assuming that there are no underlying shifts in tastes and preferences of local consumers nor any increased availability of crab from elsewhere or changes in the underlying trends in the cross elasticity of substitution for other meats, then local

[12] op cit 1

demand for Cockburn Sound crab could be expected grow, on average, by around 2.1% annually all other things remaining unchanged.

## 3.3 Drivers of Export Demand

The demand for Cockburn Sound crab in the Melbourne and Sydney fish markets will also be driven largely by population growth, changes in real per capita incomes, shifting product preferences and changing social demographics and competitive supplies available from elsewhere. These key export demand drivers are shown in Table 2 below.

**Table 2: Key Drivers of Export Demand for Cockburn Sound Crab**

| Export Markets | Population Growth (%) | Real Per Capita Income Growth[1] (%) | Aggregate Driver (%) |
|---|---|---|---|
| Melbourne | 1.24 | 0.81 | 2.25 |
| Sydney | 1.00 | 0.75 | 1.75 |
| Total | 1.11 | 0.78 | 1.99 |

[1]The real per capita income growth multiplied by an estimated income elasticity of demand of 0.30
Source: Australian Bureau of Statistics

Assuming that there are no underlying shifts in tastes and preferences of Melbourne and Sydney consumers or changes in the underlying trends in the cross elasticity of substitution for crab in these markets, then the Eastern States demand for Cockburn Sound crab could be expected to grow, on average, by around 2% annually all other things remaining unchanged.

## 3.3 Competitive Outlook and Risks

### 3.3.1Alternative Crab Supplies

In recent times, there has been significant catch of blue swimmer crab from the Shark Bay crab fishery based in Carnarvon and further north from the Nickel bay fishery based in Port Samson. Despite these alternative wild capture catches, the overall supplies of blue swimmer crab have not increased because of the annual variability of commercial catches, particularly in the Cockburn Sound crab fishery. However, if any longer term expansion in catches, particularly among the more recently established and experimental Gascoygne blue swimmer crab fisheries were to exceed the currently expected annual growth in local demand, then there could be downward pressure on local prices for Cockburn Sound crab.

### 3.3.2 Acquaculture Production of Crab

Although there is interest in aquaculture production of crab in Queensland and, more recently, elsewhere, the outcomes from these developments in the foreseeable future are unlikely to see a rapidly increased availability of crab on domestic Australian markets. These developments could pose a competitive threat to commercial wild capture blue swimmer crab, if, in the longer term, the production systems can be perfected to support large volume grow outs that prove profitable outcomes.

### 3.3.3 Local Production Costs and Productivity Gains

The changes in input costs of catching and processing blue swimmer crabs and productivity gains will impact on producer surpluses or the net benefits attributable to production from commercial use.

Of all the inputs, diesel fuel cost increases have probably been the most notable in recent times. Energy costs at the time of the earlier McLeod and Nicholls study were, on average, around 5 per cent of the total cost of catching and processing Cockburn Sound crabs. If the recent diesel price increases (net of rebates) for the catching and processing sector were around 35 per cent, then the overall total costs of catching and processing would have increased by 1.75 per cent as a result of these energy cost changes. This represents a new plateau in energy costs.

To place this in perspective, this would increase the average cost by around 6 cents/kg for the then existing catch volume shown in the earlier McLeod and Nicholls case study and reduce the aggregate average producer surpluses from $7.23/kg to $7.17/kg[13]. Given fuel tend to relatively fixed costs (that is, the level of fuel costs is not determined entirely by the catch volume, particularly in the catching sector where the bulk of the energy costs are incurred), the impact on the marginal costs is likely to be of less significance. Consequently, the impact on the marginal net benefits from commercial use is also likely to be of less significance.

Having adjusted for the recent round of the 'energy price' shocks, the central question is then what is expected to happen to general cost levels in the foreseeable future. If official sources in Australia are expecting general cost increases in the economy to be running at around 2 percent to 3 per cent annually in the foreseeable future, then this could be a reasonable assumption to use for dynamic modelling purposes. This also assumes the opportunity cost of capital are not expected to change significantly from the current level, which is probably a not unreasonable assumption in the current economic policy settings and conditions in Australia.

[13] op cit 1 Table 1, page 26

If the productivity gains in the catching and processing sector are running at the level prevailing in the fishing industry generally (that is, around 1 per cent annually), then there would be downward pressure on the net benefits attributable to production. If the assumptions about likely general cost increases mentioned above were taken to be reasonable view of the future, then this would mean that the net benefits attributable to production would be declining at a rate of around 1 per cent to 2 per cent annually.

## 3.4 The Net Impact of the Interaction between the Key Demand Drivers and Competitive Risks

Catch volumes and crab prices can be expected to fluctuate as they have in the past. The key to the application of the dynamic model is to understand how the underlying trends are likely to play out over time.

If wild harvest is at the maximum sustainable volumes and aquaculture is not expected to have any dramatic impact on product availability in the foreseeable future and the demand for blue swimmer crab increases at a rate of around 2 per cent annually, then there is likely to upward pressure on crab prices over time. If the price elasticity of demand for crab were say 0.98 as suggested by McLeod and Nicholls earlier report[14], then a 2 per cent demand expansion could be expected to see crab price rises averaging around 2.05 per cent annually over time where product availability remains broadly unchanged and assuming all other things remain unchanged. This does not mean prices will rise by 2.05 per cent every year but they will tend to fluctuate around an underlying price trend with a growth rate equivalent to the percentage amount over time.

In the event that cost increases (after allowing for productivity gains) are running against Cockburn Sound crab fishing and processing at around 1 to 2 per cent annually, then the marginal net benefits from commercial use of the Cockburn Sound crab resources are likely to increasing at around 1.05 per cent over time at best or unlikely to change materially from the earlier estimates by McLeod and Nicholls[15] at worst.

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[14] op cit 1 Figure 12, page 32

[15] op cit 1

# 4 Drivers of the Recreational Marginal Net *Benefit Values – Finding Xrec For* Cockburn Sound Crab

The application of the allocation model on the recreational side requires that we have an estimate of X*rec* in the basic equation:

$$MB_{rec}^{t} = MB_{rec}^{0}(1 + X_{rec})^{t} \text{ , where}$$

- $MBrec^t$ is the recreational marginal net benefit in the future time period t.
- $MBrec^0$ is the recreational marginal net benefits determined from the application of the static model specified in previous research by McLeod and Nicholls[16]. This sets the values for the base period, period 0.
- X*rec* is the percentage annual growth in the benefits; that is the expected annual growth in MB*rec*.

In estimating X*rec* we need to incorporate the various drivers of recreational value as annual percentage growth rates.

Recreational crab fishing currently has about 550 to 600 participants. Hence it is a very small activity and virtually insignificant in terms of the general population. Based on the surveys in McLeod and Nicholls[17], retirees and pensioners, that is the over 60's, represented 30 per cent of fishers. Those in their 30's, 40's, and 50's each accounted for about 20 per cent of the group. Annual incomes of between $26,000 and $36,399 had the most number of respondents

For Cockburn Sound Crab the key to the estimation of X*rec* is to assess how:

- the willingness to pay will increase for the existing participants (the 500-600),
- how the participation rate will increase (the new participants).

In looking at these factors we can focus on some key drivers. First consider the existing fishers. We expect that their demand for crab will increase as a function of:

- annual population growth. In Western Australia this is around 1.7% per annum.
- annual growth in real income per capita. In Western Australia this is about 2.5% per annum, although this may not apply to the specific crab fishers given their age and income distribution.

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[16] op cit 1.

[17] op cit 1

- income elasticity of demand for recreational crab fishing
- change in the demographic composition of the population over time. For recreational fishing, participation rates and type of fishing appear to vary with age.
- annual percentage change in the underlying real local prices of alternative recreational activities and the cross elasticity of substitution between these alternatives and recreational Cockburn Sound crab fishing. If prices of alternative activities falls relative to the "price" of fishing then consumers will shift towards these activities and away from recreational Cockburn Sound crab fishing.

For Perth metropolitan area population is around 1.6 million so relative to population the actual participation rate is very low, at less than 1%.

At only 500-600 participants and minimal costs of entry there is clearly scope for participation rate (% of population crab fishing) to grow. However, whilst there is no hard evidence on the way that the participation rate may grow, the anecdotal evidence is that crabbing in the Sound is not likely to be a high growth activity[18]. For the base case zero has been assumed for growth in the participation rate.

The overall Perth population is expected to growth at 1.7% per annum. However, it is an aging population with the 55 to 59 age group is expected to grow by 5.9% per annum and 60 to 64 age group expected to grow by 4.9% pa. Keeping the participation rate unchanged means that the cohort of 500 to 600 fishers grows at the population growth rate, somewhere around 1.75 per annum.

Real per capita incomes in Australia have grown by around 2.5 % per annum over the last decade and this is expected to continue for some years.

There is no data on the income elasticity for recreational Cockburn Sound crab fishing. A value of 1.0 has been assumed, reflecting more the view that Cockburn Sound crab is a catch primarily to eat.

Using these variables we can consider how the demand for recreational Cockburn Sound crab fishing activity might rise.

Combining the population growth and per capita real income growth (with an income elasticity of 1) gives an overall growth in demand of 4.2% per annum.

[18] Unlike say wetline fishing. As the number of retirees with boats increases and time become available we could see increasing participation in fishing on the reefs for the prized dhufish and pink snapper.

However, if the participation rate increased by 1% per annum, then overall demand growth would be 5.3%. But given the uncertainty regarding the attractiveness of crab fishing to future retirees, we have used 4%.

This is demand to catch additional kilograms of crab against the current allocation of 18,000 kilograms of crab.

# 5 Making the Model Operational

The key parameters described in previous sections can be used to calibrate the allocation model. This is done using the Cockburn Sound Crab specific version of the illustrative model described in Lindner, McLeod and Nicholls[19].

Taking the model and the specific crab functions as set out above produces a spreadsheet model solution as shown in below.

The growth rates, X*rec* and X*com* come from the work in Chapters 3 and 4.

The marginal net benefit from commercial crabbing is based on the original study which was estimated to be $ 4.37 per kilogram.

The value for the recreational sector was derived from the original contingent valuation study. The linear specification from that study for willingness to pay function was used to derive a marginal willingness to pay function and to determine the way that the marginal willingness to pay changes as crabs are allocated toward the recreational sector.

The basic recreational choice equation takes the form of a logistic regression with a form:

$$Log[\frac{\Pr ob(yes)}{1-\Pr ob(yes)}] = \alpha_0 - \beta_1 FEE + \beta_2 QTY + \sum \beta_i SOCIO = \Delta V$$

where FEE is the specified fee, QTY is the specified quantity, and SOCIO is set of socio demographic and attitudinal variables. For the crab fishery the socio economic variables were not significant and the linear functional form in fee and quantity appeared to work best where the estimates of coefficients were $\beta_1$=-0.705 and $\beta_2$=0.233

The marginal willingness to pay or part worth is defined in terms of the trade off between quantity and price which is of the form:

Marginal willingness to pay = $-(\partial(\Delta V)/\partial QTY)/(\partial \Delta V/\partial Fee)$,

For the inverse case this is: $-(\beta_2/\beta_1)$

In order to solve for the optimal allocation we have to allow for the fact that as stock is adjusted between sectors the relative marginal valuations change. As stock is

[19] op cit 2

allocated to the recreational sector we would expect the marginal valuation of further allocations to decline, all other things equal.

In the current case study the marginal value of commercial catch declines. However, as was shown in the previous case study[20], the marginal recreation benefit of additional crab appears constant based on the linear specification of the logistic choice equation. Based on the linear choice model, the marginal willingness to pay function is $(-\beta_2 / \beta_1)$. Using the previously derived estimates of $\beta_1$=-0.705 and $\beta_2$=0.233 gives a constant marginal willingness to pay of $3.02 per crab for recreational fishing

Figure 4, Figure 5 and Figure 6 show the allocation results when the *Xrec* is 4% per annum and *Xcom* is 1%, a 3% spread.

The analysis of commercial drivers indicates that this is a generous *Xcom* figure and various factors such as aquaculture growth suggest an even greater downward pressure on commercial values. A figure of 0% or even a negative growth is plausible. Similarly, the balance of probabilities suggests that the recreational growth may be lower than the 4% used. Crab appears to be a lower income retiree activity where age and habit play an important role. However, older age cohorts grow even faster than the general population and this may increase participation numbers.

Figure 7, Figure 8, Figure 9 and Figure 10 show the allocation outcome when *Xrec* at 4% pa and *Xcom* at 0% per annum are used. Figure 8 shows how the allocation share changes while Figure 9 shows the magnitudes of allocation adjustments needed over time.

[20] McLeod and Nicholls,2004.

| Assumptions | | | | |
|---|---|---|---|---|
| Annual Growth Rate in Recreational Net Benefits | $X_{rec}$ | | 0.04 | |
| Annual Growth Rate in Commercial Net Benefits | $X_{com}$ | | 0.01 | |
| Marginal Net Benefit Recreational Catch Base Year | MB *rec,0* | $ | 5.33 | |
| Marginal Net Benefit Commercial Catch Base Year | MB *com,0* | $ | 4.37 | |
| Fish Stock to Be Allocated | Q | | 230000 | kgs |
| Intial Recreational Allocation | Q *rec,* 0 | | 18000 | kgs |
| Initial Commercial Allocation | Q *com,0* | | 212000 | lgs |
| Marginal Benefit Functions From Base Year Estimation | | | | |
| Recreational MB fucntion constant | $\alpha_{rec}$ | | 0.233 | |
| Commercial MB function constant | $\alpha_{com}$ | | -2.25549E-05 | |
| Recreational MB fucntion slope | $\beta_{rec}$ | | -0.705 | |
| Commercial MB function slope | $\beta_{com}$ | | 0 | |

**Figure 4: Data Sheet For Cockburn Crab Time Path Model Scenario 1**

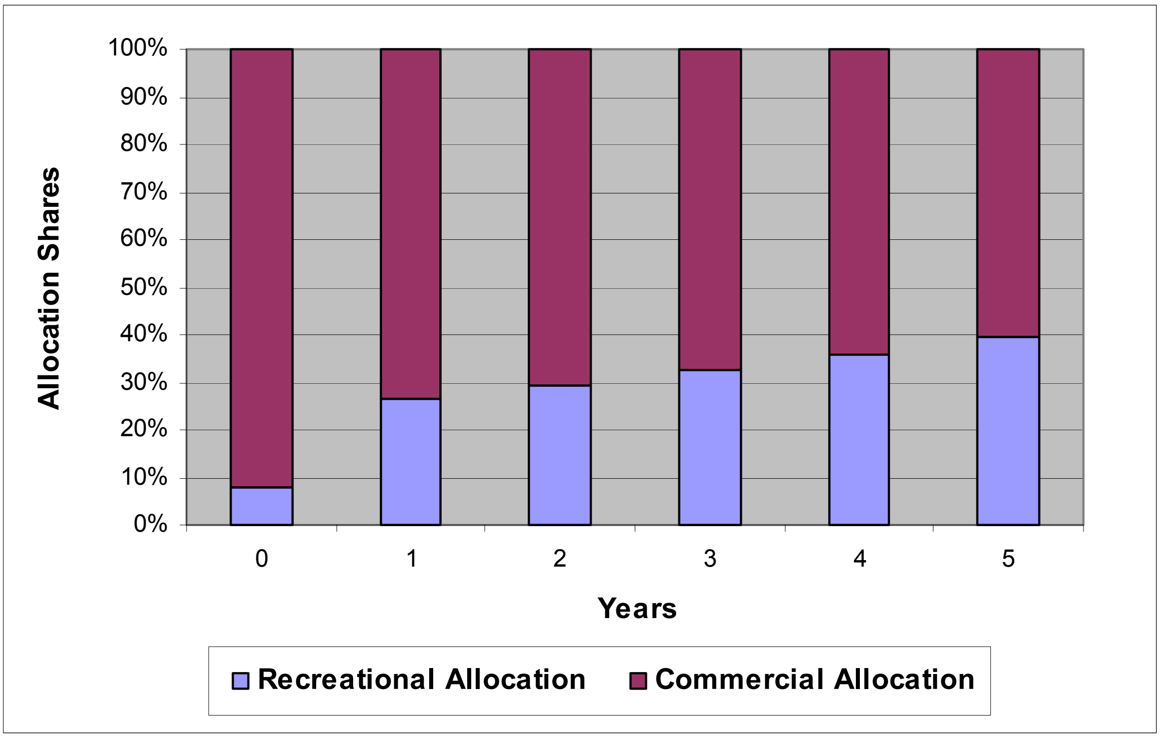



**Figure 5: Time Path of Cockburn Crab Stock Allocation for Scenario 1**

| Year | 0 | Year 1 | | Year 2 | | Year 3 | | Year 4 | | Year 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj |
| Q | 230000 | 230000 | 230000 | 230000 | 230000 | 230000 | 230000 | 230000 | 230000 | 230000 | 230000 |
| Q rec | 18000 | 18000 | 60563 | 60563 | 67669 | 67669 | 75057 | 75057 | 82692 | 82692 | 90667 |
| Q com | 212000 | 212000 | 169437 | 169437 | 162331 | 162331 | 154943 | 154943 | 147308 | 147308 | 139333 |
| MB rec,t | 5.33 | 5.33 | 5.33 | 5.54 | 5.54 | 5.76 | 5.76 | 6.00 | 6.00 | 6.24 | 6.24 |
| MB com,t | 4.37 | 4.37 | 5.33 | 5.38 | 5.54 | 5.60 | 5.77 | 5.82 | 6.00 | 6.06 | 6.24 |
| MB Diff | 0.96 | 0.96 | 0.00 | 0.16 | 0.00 | 0.17 | 0.00 | 0.17 | 0.00 | 0.18 | 0.00 |
| change in commercial allocation required to optimize allocation, year t | | | -42563 | | -7107 | | -7388 | | -7635 | | -7975 |
| change in recreational allocation required to optimize allocation, year t | | | 42563 | | 7107 | | 7388 | | 7635 | | 7975 |

**Figure 6: Worksheet for Optimal Time Path of Allocation Showing Annual Adjustments in Allocation of Cockburn Crab. Scenario 1**

| Assumptions | | | | |
|---|---|---|---|---|
| Annual Growth Rate in Recreational Net Benefits | *Xrec* | | 0.04 | |
| Annual Growth Rate in Commercial Net Benefits | *Xcom* | | 0.00 | |
| Marginal Net Benefit Recreational Catch Base Year | MB *rec,0* | $ | 5.33 | |
| Marginal Net Benefit Commercial Catch Base Year | MB *com,0* | $ | 4.37 | |
| Fish Stock to Be Allocated | Q | | 230000 | kgs |
| Intial Recreational Allocation | Q *rec,* 0 | | 18000 | kgs |
| Initial Commercial Allocation | Q *com,0* | | 212000 | lgs |
| Marginal Benefit Functions From Base Year Estimation | | | | |
| Recreational MB fucntion constant | $\alpha_{rec}$ | | 0.233 | |
| Commercial MB function constant | $\alpha_{com}$ | | -2.25549E-05 | |
| Recreational MB fucntion slope | $\beta_{rec}$ | | -0.705 | |
| Commercial MB function slope | $\beta_{com}$ | | 0 | |

**Figure 7: Data Sheet For Cockburn Crab Time Path Model Scenario 2**

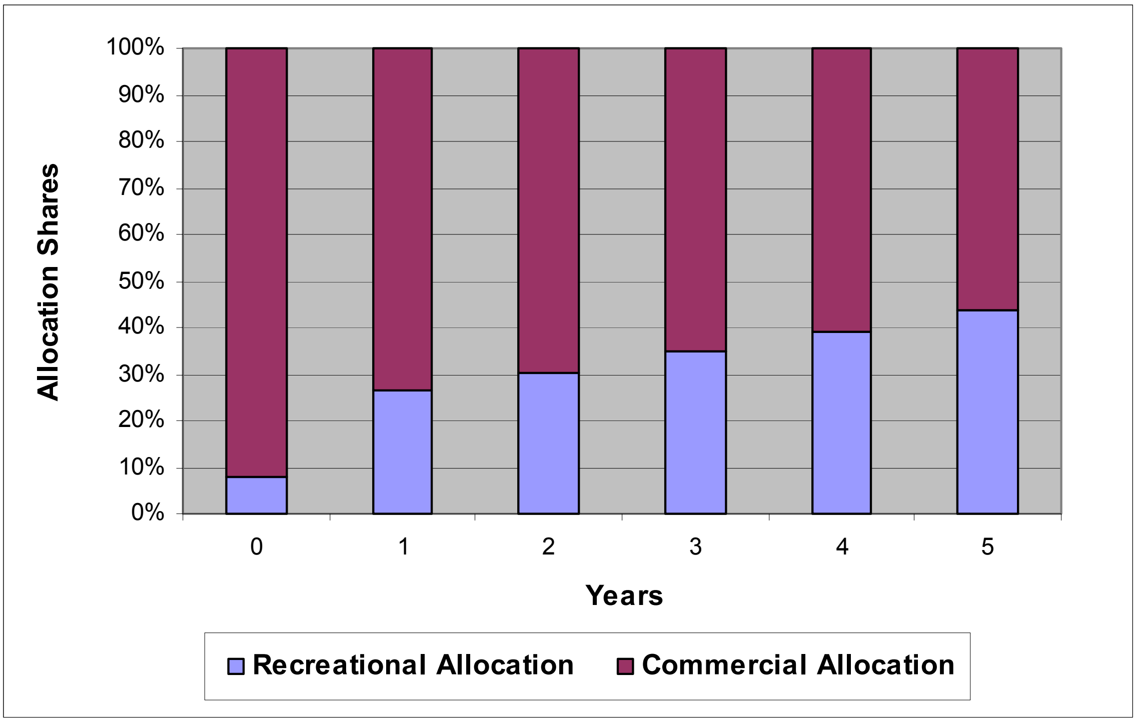



**Figure 8: Time Path of Cockburn Crab Stock Allocation for Scenario 2**

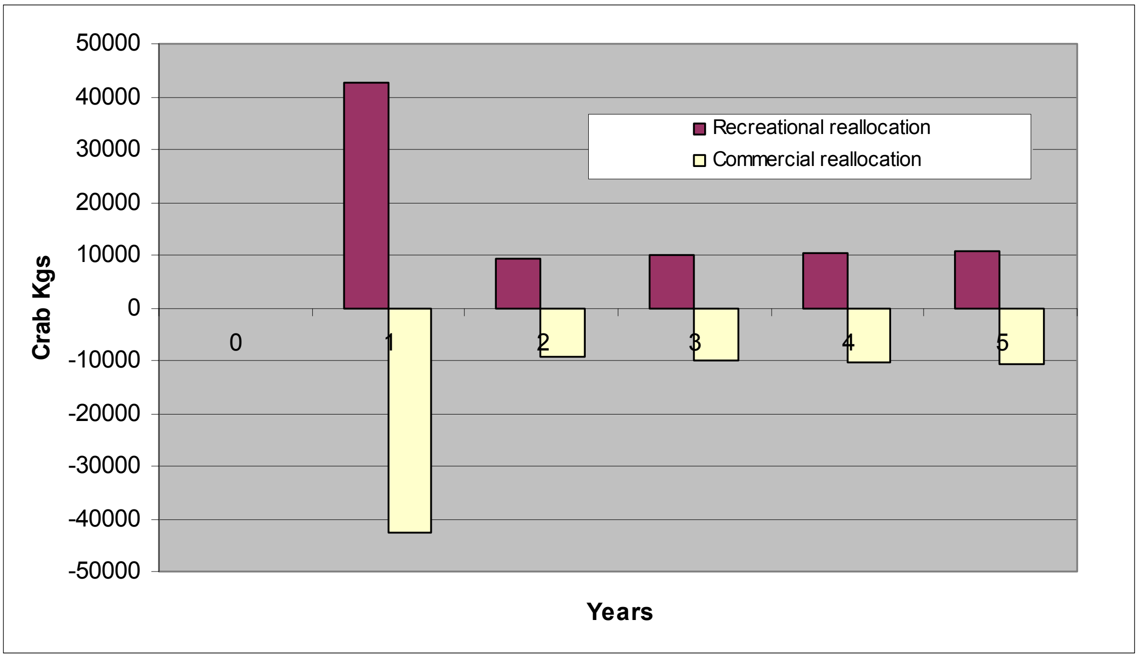



**Figure 9: Quantity Adjustments Along Time Path of Cockburn Crab Stock Allocation for Scenario 2**

| | Year 0 | Year 1 | | Year 2 | | Year 3 | | Year 4 | | Year 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj |
| Q | 230000 | 230000 | 230000 | 230000 | 230000 | 230000 | 230000 | 230000 | 230000 | 230000 | 230000 |
| Q rec | 18000 | 18000 | 60563 | 60563 | 70015 | 70015 | 79846 | 79846 | 90070 | 90070 | 100702 |
| Q com | 212000 | 212000 | 169437 | 169437 | 159985 | 159985 | 150154 | 150154 | 139930 | 139930 | 129298 |
| MB rec,t | 5.33 | 5.33 | 5.33 | 5.54 | 5.54 | 5.76 | 5.76 | 6.00 | 6.00 | 6.24 | 6.24 |
| MB com,t | 4.37 | 4.37 | 5.33 | 5.33 | 5.54 | 5.54 | 5.76 | 5.76 | 6.00 | 6.00 | 6.24 |
| MB Diff | 0.96 | 0.96 | 0.00 | 0.21 | 0.00 | 0.22 | 0.00 | 0.23 | 0.00 | 0.24 | 0.00 |
| change in commercial allocation required to optimize allocation, year t | | | -42563 | | -9452 | | -9831 | | -10224 | | -10633 |
| change in recreational allocation required to optimize allocation, year t | | | 42563 | | 9452 | | 9831 | | 10224 | | 10633 |

**Figure 10: Worksheet for Optimal Time Path of Allocation Showing Annual Adjustments in Allocation of Cockburn Crab. Scenario**

# 6. Policy Implications

The results from the application of the dynamic model to the Cockburn Sound Crab fishery shown in Chapter 5 give decision makers and stakeholders an insight into the optimal allocation path over time. The model outcomes highlight the direction, extent and timing of stock re-allocations required in the future between the commercial and recreational sectors if socially optimal allocations are to be achieved and maintained.

If the total sustainable take were 230,000 kilograms and assuming the commercial marginal net benefits are increasing at around 1% annually (that is, Xcom = 0.01) and the recreational benefits are growing at around 4% annually (that is, Xrec = 0.04), then the dynamic model outcome for the Cockburn Sound Crab fishery suggests a stock re-allocation of up to 72,667 kilograms or around 213,000 animals annually towards the recreational sector by the end of 5 years. This represents a re-allocation of around one-third of the animals taken by the commercial sector in year 0 to the recreational sector.

These results also indicate that a substantial re-allocation adjustment of up to 43,000 kilograms or about 126,000 animals in year 1, then significant re-allocation adjustments of up to 7,000 kilograms or about 20,500 animals in each of the subsequent 4 years. This is because the recreational marginal net benefits, which remain fairly constant across this volume range, are growing faster than the commercial marginal valuations even at the reduced volumes after resource re-allocation.

In practical terms, the lumpiness of any initial re-allocation will need to be effected through a substantial reduction in commercial effort in the form of reduced pot numbers operated by commercial fishers and adjustment to the daily bag limit for the recreational sector. These commercial effort and recreational bag limit adjustments may not be able to ultimately match the required resource re-allocation adjustment. For instance, an increase in the daily bag limit from 24 to around 75 at the beginning of year 1 would potentially re-allocate around 126,000 animals annually in that year assuming there is sufficient unsatisfied demand among recreational fishers to take up the increased retention limit. If the participation rate among the faster growing retiree segment of the population were to remain unchanged, then there would be a further re-allocation in year 2 of around 8,800 animals to the recreational sector and potentially the same in each of the next 3 years. This is because there is no limit on recreational entry into the fishery.

Likewise, there can be no certainty that a 20 per cent reduction in the pot numbers held by commercial sector from 850 to 680 pots in that year will result in the commercial catch declining by the required 126,000 animals in that year. Typically, commercial fishers can adjust effort in various ways to try to minimize the impact of pot reductions of such magnitude. Also, the size of this adjustment to the commercial sector may justify consideration of some other fisheries adjustment strategies in year 1 that explicitly allows the beneficiaries to compensate the losers from this initial resource re-allocation. In allocation theory, this should provide an objective test of whether the expected benefits at least outweigh the losses and perhaps still leave the beneficiaries better off.

An appropriate course of action in this case might be to make the initial year 1 re-allocation adjustment within perhaps a suitable restructure package, and then review the allocation options including a recalibration of the static and dynamic models in year 5, unless monitoring of sustainability indicators or key drivers identified in Chapters 3 and 4 highlight material changes are taking place that justify an earlier review of catch levels and allocations.

In this way the model allows structured thinking about the best course of adjustments over time.

An important consideration is whether the changes are asymmetric. In this case they are in that all reallocation is towards recreational activity. With this knowledge and the estimate of the scale of the adjustment needed, the pattern of adjustment can be planned to achieve the best outcome over the five year period making due allowance for any adjustment/transaction costs.

The dynamic model is also capable of sensitivity analysis. The results show that, if the commercial net benefits were not expected to increase as much in the foreseeable future (that is Xcom = 0) and recreational benefits remained the same (that is, Xrec = 0.04) then the outcomes, whilst different in terms of the extra number of animals to be re-allocated annually by year 5 to achieve socially optimal outcomes (around an extra 77,000 animals annually by year 5) would not justify a change to re-allocation policy path but may warrant some tinkering with the magnitude of the initial re- allocation adjustments outlined above.

The results from the application of the dynamic model to the Cockburn Sound crab fishery assume the total ‘year-in, year-out’ sustainable take is around 230 tonnes or around 675,000 animals. This is uncertain given the recent catch history in this fishery. However, this could be due to short term biological factors.

The modelling also assumes the intra-sectoral allocations are optimal, that is the catch limits are binding on all fishers (commercial and recreational) and extra gains to either sector from an increased share of the defined sustainable catch. The previous research by McLeod and Nicholls highlighted that, whilst this was most likely the case in the commercial sector with transferable pot entitlements, the position was ambiguous in the recreational sector.

In a policy context, this means the intra-sectoral allocation issues in the recreational sector should be resolved first through greater choice of entitlements (e.g. days fished, and/or bag limits) before the inter-sectoral allocation options are addressed. This is because the recreational marginal net benefits can change once the intra-sectoral issues are resolved and because the recreational marginal benefit curve may also change after the intra-sectoral issues are resolved.

ERA
ECONOMIC RESEARCH ASSOCIATES

# DYNAMIC MODELLING OF THE SOCIALLY OPTIMAL ALLOCATION OF FISH RESOURCES BETWEEN COMMERCIAL AND RECREATIONAL USE

## (FRDC Project 2003/039)

## PART THREE

## PERTH ABALONE FISHERY CASE STUDY

**By R Lindner, P McLeod and J Nicholls**

# FOREWORD

The Perth Abalone Fishery is one of three case studies used to calibrate the socially optimizing dynamic model for evaluating allocation options for fish stocks between recreational and commercial fishing. This is outlined in Part A of this research project.

This project builds on previous FRDC-funded research by Hundloe, *et al* and by McLeod and Nicholls. The later research (FRDC project 2001/065) provided fisheries managers and stakeholders with a framework and methodology to estimate and compare marginal values of fish caught by the commercial and recreational sectors on a sound and consistent basis.

The case studies fisheries are the same as those used by McLeod and Nicholls in their previous research to demonstrate the application of the general theoretical framework and methodologies for a single period, static, model outlined in that previous research. The other two are the Cockburn Sound crab fishery and the West Coast 'wetline' fishery.

This Abalone fishery case study uses and builds on the methodology and information discovered and described in that earlier research.

As a result of this and the earlier research mentioned above, fisheries managers and stakeholders have access:

- To a clear explanation of the appropriate conceptual framework for resource decisions; and
- To sound and consistent guidelines for applying suitable tools to estimate comparable values for evaluating resource allocation between competing uses and for determining the socially optimal allocation path for fish resource stock.

Whilst this research focused on recreational and commercial uses, the conceptual framework and valuation methodologies and tools are capable of being applied to evaluate a wider set of allocation options (passive and non-passive) for a fish resource stock on a sound and consistent basis.

**Economic Research Associates**

**August 2006**

## CONTENTS

# TABLES AND FIGURES

# 1 INTRODUCTION

The Perth Abalone fishery is one of three case studies designed to provide practical guidance to fisheries management and stakeholders in the application of the general theoretical framework and dynamic modelling tool to address the socially optimal allocation path of fish stocks between the commercial and recreational fishing sectors.

Earlier research by McLeod and Nicholls[1] provided a conceptual framework and methodological tools for estimating the appropriate marginal values for recreational and commercial fishing at a point in time on a sound and consistent basis and for determining the socially optimal allocation at that point in time. This was applied to the Perth abalone fishery as one three case studies used to demonstrate the application of this theoretical framework and static modeling tool.

The abalone case study results provided a benchmark of the marginal values of commercial and recreational use and socially optimal allocation in the fishery at a point in time. However, whilst it is critical to identify socially optimal allocations at a given point in time, it is equally important to recognize that this solution is likely to change over time.

The insights gained from their existing research led McLeod and Nicholls[2] to highlight that the determinants of fish stock values are likely to change over time as the underlying determinants of these values change. However, whilst fisheries management have a well defined framework and tested tools for comparative statics from that previous research, decision makers around Australia considered that there would be value in a supplemented framework and tested dynamic tools that are capable of modelling the impact of changes in key drivers on commercial and recreational relative values over time, and on consequential changes in the socially optimum allocation through time.

The current study develops a dynamic model that can be used to consider the way that relative marginal values may change over time and how this may affect the optimal resource allocation. The basic theory of the model was developed in Lindner, McLeod and Nicholls[3]. This report calibrates the model for the abalone fishery.

---

[1] McLeod ,P and Nicholls,J. 'Socio-Economic Valuation of Resource Allocation Options between Commercial and Recreational Sectors' FRDC Project 2001/065. FRDC: Canberra. 2004.

[2] Op cit 1

[3] Lindner, R, McLeod, P and Nicholls, J. 'Dynamic Modelling of Socially Optimal Resource Allocation: Part A, A general Theoretical Framework.' FRDC Project 2003/039. FRDC: Canberra. 2005.

## 1.1 The Report Structure

Chapter 2 looks briefly at the fishery and the outcomes from the application of the basic static allocation model and describes what is needed to develop the dynamic model of allocation for the abalone fishery. Chapter 3 looks at the marginal net benefit from commercial catch and the key drivers that cause the marginal commercial value to change over time. Chapter 4 looks at the marginal net benefit from recreational abalone catch and the key drivers that change this marginal net benefit over time. Chapter 5 puts these into a dynamic framework that allows the direction of the change in the socially optimum allocation of abalone through time to be estimated. Chapter 6 summarizes the model results with indicative policy conclusions.

# 2 Overview of Abalone Fishery, Static and Dynamic Allocation Models

## 2.1 Management Regime in the Abalone Fishery

Recreational and commercial fishing in this localized Roe abalone fishery is subject to catch controls combined with spatial, temporal and biological controls. The catch control in the limited-entry commercial fishery takes the form of unitized individual transferable catch quota (kilograms), whilst recreational fishing is subject to a daily bag limit (20 abalone) and open to anyone who is willing-to-pay the seasonal recreational license fee of A$34.

Recreational fishing is limited to 90 minutes on each of six Sundays in November to December and commercial fishing during the recreational season is prohibited. The minimum sizes of the animals that can be taken by recreational (60mm) and commercial (70mm) sectors define, to a degree, different products.

The annual commercial catch quota is 36 tonnes, whilst the recreational take is estimated by the Fisheries Department to be around 40 tonnes at the time of the previous research by McLeod and Nicholls[4].

## 2.2 Original Static Model Results

The previous study by McLeod and Nicholls estimated the marginal net benefit from commercial and recreational use on the assumption that existing effort and catch of around 76 tonnes in the Perth roe's abalone fishery is sustainable. The results of that analysis are shown in Figure 1 below.

[4] Op cit 1.

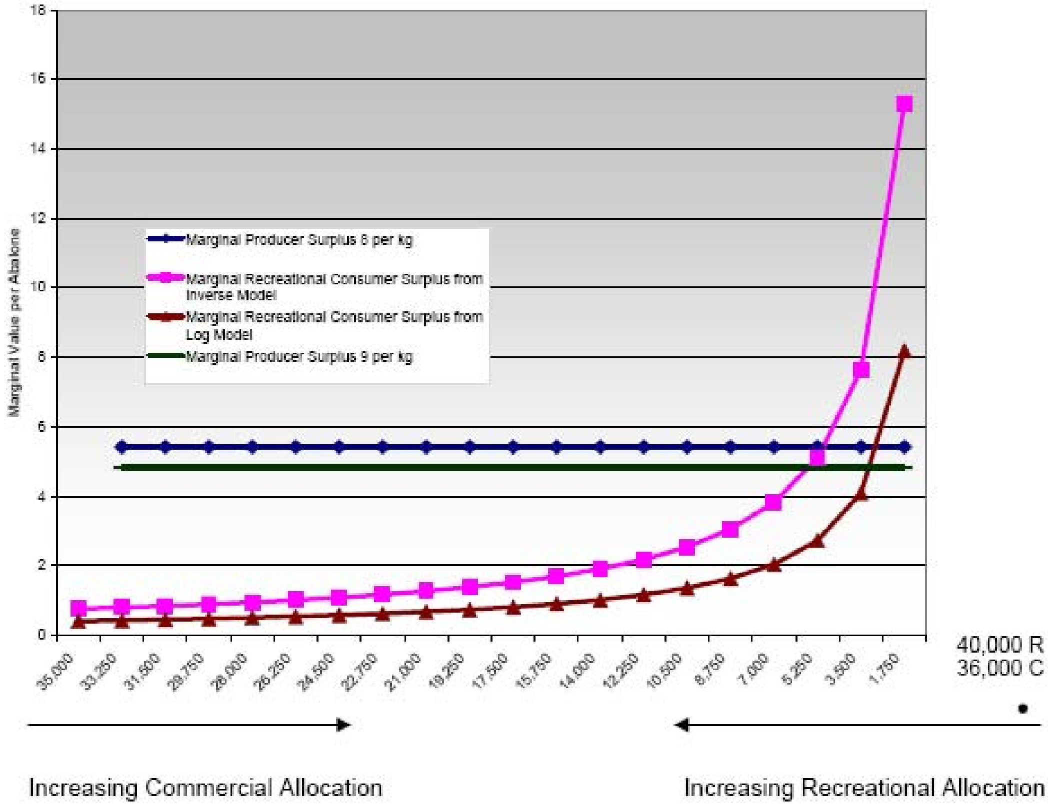



**Figure 1: Marginal Net Benefits of Commercial and Recreational Use in the Perth Abalone Fishery**

The commercial net benefits are derived entirely from producer surpluses as virtually all of the commercial roe's abalone catch from the Perth fishery is exported. In consequence, there are no marginal net benefits attributable to local 'retail' consumption that need to be taken into account.

On the recreational side, the data available indicated that use value dominated and that experiential (and other) values typically associated with recreational fishing were not significant for the roe's abalone fishery.

The relationship between the marginal benefits for commercial and recreational use is for a defined volume range. This reflects the underlying supply and demand conditions on the commercial side and the underlying preferences on the recreational side for Perth roe's abalone.

The marginal producer surplus for the commercial side is a constant based on the assumption that the Perth roe's abalone industry is a 'price taker' (that is, supply changes will have no impact on prices received) and that the marginal costs change little over the volume range.

The right hand origin in Figure 1 above is the then current allocation. Working from right to left the diagram shows additional allocation to the recreational sector. At the existing catch shares of around 40,000 kilograms for recreational and 36,000 kilograms for commercial, the analysis shows that, for the next additional abalone, the marginal benefits to recreational use are estimated to be higher than the marginal benefit from commercial use.

If the existing catch levels are accepted as defining the total sustainable catch in the fishery, then a reallocation of up to another 4,500 kilograms of abalone to the recreational sector is indicated. This would increase the overall benefit to society from the combined commercial and recreational use of the resource. This is because the marginal benefit of an extra abalone allocated to recreational use at that point in time is greater than the loss in producer surplus at the margin from commercial use up to this tonnage. Beyond this extra 4,500 kilograms, the marginal benefit to commercial use exceeds those from recreational use across the remainder of the volume range.

As shown in the Figure 1 above the result does not differ markedly if the commercial conversion factor is based on 8 or 9 abalone to the kilogram of whole abalone. If a conversion factor of 9 abalone to the kilogram were used, the corresponding reallocation figure at that time is up to 4,000 kilograms. The difference between the two results would be equivalent to an increase in the bag limit of around three compared to four.

## Underlying Assumptions for Applying Optimal Resource Sharing Models

This previous analysis of the abalone fishery was based on the following assumptions:

- The combined existing commercial and recreational catch of 76 tonnes is all that is sustainable and available for inter-sectoral allocation, but this is ambiguous under the existing management regime;
- All recreational participants are subject to binding constraints (bag limits, fishing days and time), that is, there is no unused or spare capacity, but the survey results at that time showed that this was not the case for many recreational fishers in the Perth abalone fishery. This meant that the marginal values for recreational fishing possibly overstated those that might exist otherwise under a recreational management regime that gave recreational fishers greater choice of bag limits, fishing days and time within the current constraints and fee structure;
- For all commercial operators it is optimal to take the current allowable catch, that is, there is no unused or spare capacity and the survey data at the time tended to support this possibility;

- All commercial operators are internally structured to maximize producer surpluses from roe's abalone catches in the Perth fishery, and, given the scope to restructure through quota unit transfers among commercial licensees, this is most likely the case; and
- The fish stock to be shared between commercial and recreational sectors are the same, but this was ambiguous in terms of both the stock being fished (recreational fishing restricted to reef tops whilst commercial constrained to fishing around the reef edges) and the differences in the minimum size of the abalone that can be taken by recreational and commercial fishers.

However, for the purposes of applying the dynamic model, these limiting factors are assumed to be not present.

## 2.3 Applying the Dynamic Model to Abalone

The starting point for the application of the dynamic model is the dynamic framework developed in Lindner, McLeod and Nicholls[5] and the static model marginal values and optimal allocation results from the previous study by McLeod and Nicholls[6].

In essence we have to take the marginal net benefit functions as shown in Figure 1 and fit them into the dynamic framework shown in Figure 2 and Figure 3 below.

[5] Lindner, McLeod and Nicholls, 2005.

[6] McLeod and Nicholls, 2004.

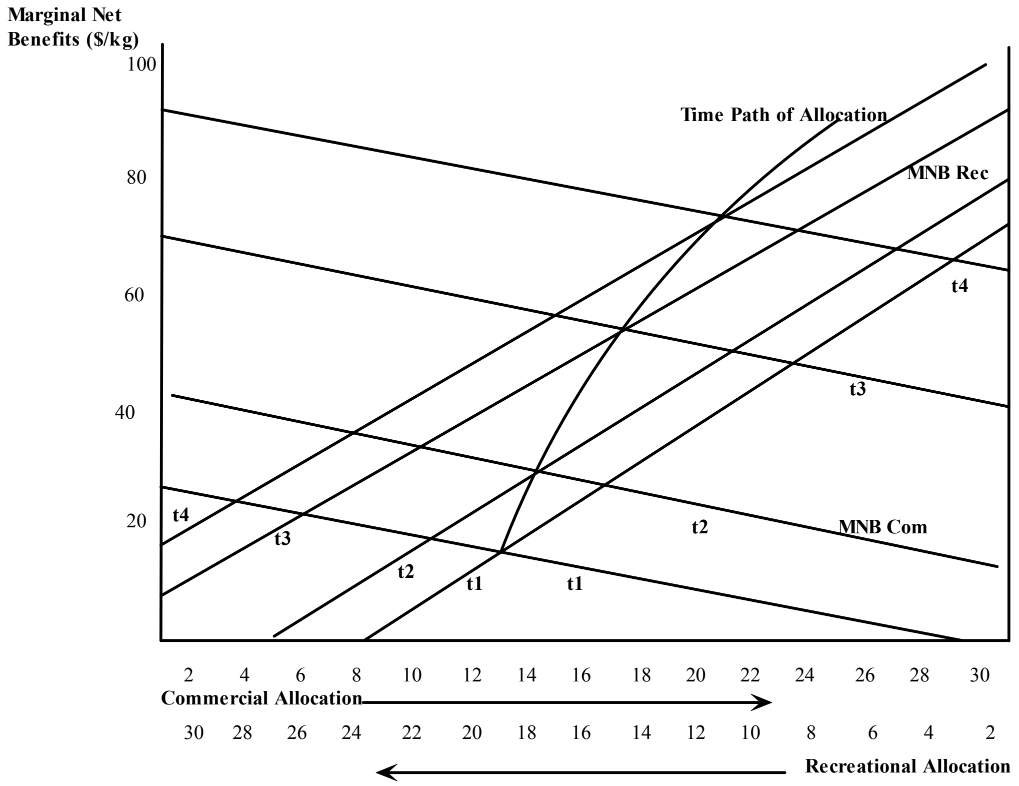



**Figure 2: Optimal Time Path of Allocation When Shift is Toward Commercial Abalone Sector**

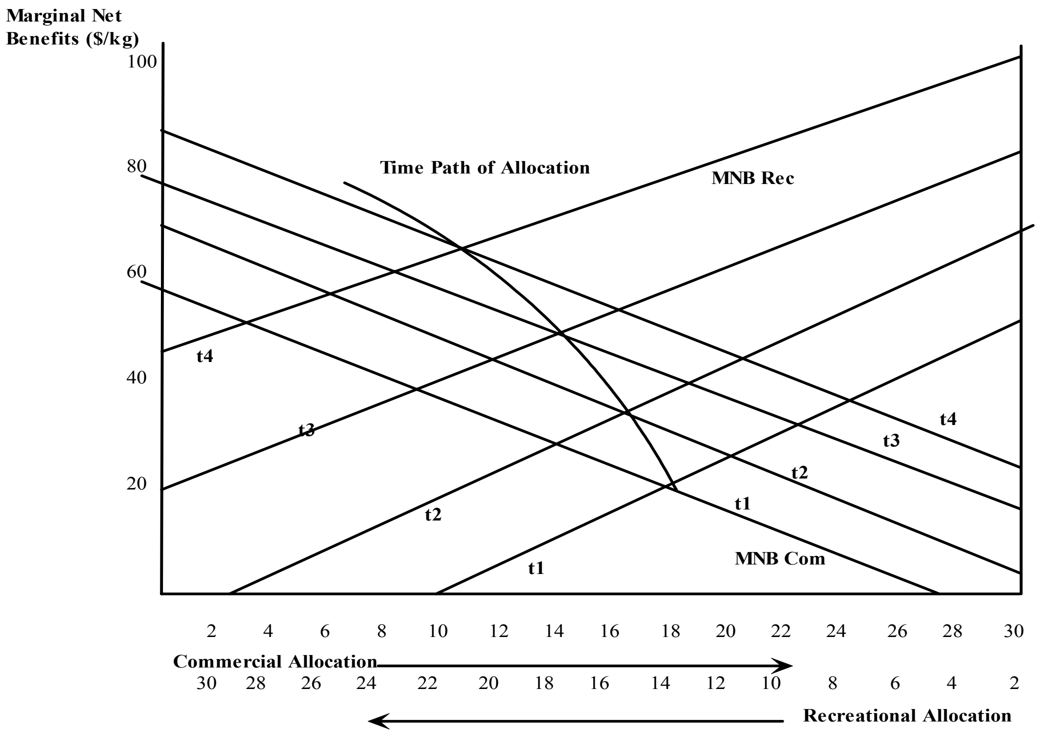



**Figure 3: Optimal Time Path of Allocation When Shift is Toward the Recreational Abalone Sector**

In Figure 2, the time path of allocation moves toward commercial abalone sector over the four time periods t1 to t4. In Figure 3 the time path moves toward recreational abalone sector in each of the four time periods.

These diagrams assume that we start from the optimal initial allocation such as that shown for abalone in Figure 1 above. However, in Figure 1, the optimal allocation requires an adjustment toward recreational use to achieve an initial optimal allocation. The existing allocation was therefore suboptimal in the current environment and the dynamic model needs to cope with this.

The application of the dynamic model is based on identifying the key variables that affect commercial and recreational values over time, and the way they will change relative to each other over time. That is, it is based on formulating relationships that determine how the commercial and recreational marginal valuation schedules shown in Figure 2 and Figure 3 change over time.

The sort of variables that will shift these relationships include variables related to demography, biology, technical change including aquaculture developments, and underlying economic drivers and related market conditions.

The dynamic model is not designed to specify precise optimal allocation solutions at future points in time in terms of exact quanta for the abalone fishery.

Rather it will help fisheries managers and stakeholders to make informed stock re-allocation decisions today in the knowledge of the likely future trends in the relevant values relative to commercial and recreational fishing for abalone and the implications of the trends in these values for the likely direction of optimal stock allocation of abalone tomorrow. The analysis is based on the notion of a total allowable catch that will be in existence over time and which is to be allocated optimally between the commercial and recreational sectors in a zero sum game framework

An important outcome of dynamic modelling is that it will enable formulation of a smooth allocation path over time (with typically five to ten year timeframes) that is consistent with longer run economic, biological, demographic and other social trends shifting the relative benefits of commercial and recreational use through time. This will enable fisheries managers to take a more strategic approach to resource allocation for abalone by providing them with a practical interpretative tool that can forecast the direction of appropriate future fish stock allocations.

## 2.4 The Dynamic Model for Abalone

In developing the basic framework for analysing the path of likely allocation adjustments over time, the logical starting point is to consider the relationships that lie behind the marginal net benefit schedules for commercial and recreational fishing. There are two parts to this. First, we need a framework for each marginal net benefit schedule that will enable us to understand and analyse the way that key variables influence changes in marginal net benefits. Second, we need a relatively straightforward framework or model that will allow us to calibrate the key relationships and shape of the time path of allocation adjustment over time.

The first fit neatly within the demand and supply framework and its application to commercial and recreational activities are considered in the previous two sections. The second fits well with those models in economics which focus on relative growth rates for net benefits as part of benefit cost analysis of policy evaluation. This is considered in the next section.

## 2.5 Mathematical Model of Optimal Allocation Time Path for Abalone

In order to develop a decision making approach to allocation in future periods we need to translate the thinking from the previous sections into a formulation of the optimal time path of allocation. The starting point is the static model and associated results as reflected in Figure 1.

The commercial marginal net benefit is a constant. That is, within reason, the marginal net commercial benefit per kg is not affected by the quantum of abalone allocated to the commercial sector.

The recreational marginal net benefit schedule is derived from the logistic choice model that was estimated in McLeod and Nicholls[7]. This was based on a contingent survey of abalone fishers which focused on their marginal willingness to pay for additional abalone bag limits. This is based on the best fitting logistic equation which was an inverse specification.

From any starting point there are in fact an infinitive number of allocation paths. Ideally we would to choose the one that maximized the value of the stream of benefits (the sum of commercial and recreational net benefits) over time. The economic approach to this is to maximize the net present value of this benefit stream as shown in the following equation.

$$NPV_{TP} = \sum_{i=1}^{i=n} \frac{B\mathrm{Re}c,i + BCom,i}{(1+r)^i}$$

.

[7] McLeod and Nicholls, 2004,

If we maximize the NPV, subject to the absolute total allowable catch we will be selecting the optimal time path of allocation of the catch between the recreational and commercial sectors and maximizing the social value of the fishery. We know the sustainable catch to be allocated over time is given and we will assume that this is fixed. At any point in time the optimal allocation occurs where:

.

$$MNB\,\mathrm{Re}c, 0 = MNBCom, 0$$

Under this assumption no upfront adjustment is needed to the allocation. We just need to keep the equality in place over time by adjusting the allocation. To do this requires that we forecast the commercial and recreational marginal benefit value for each future year and solve for the allocation that equates the forecast recreational and commercial marginal benefits.

Based on the dynamic model developed in McLeod and Nicholls[8], we begin with the fully documented base values for abalone for both commercial and recreational use.

For the recreational sector the base value is assumed to grow (decline) according to the relationship:

$$B\,\mathrm{Re}c, i = B\,\mathrm{Re}c,_0(1 + X\,\mathrm{Re}c)^i$$

For the commercial sector the base value is assumed to grow (decline) according to the relationship:

$$BCom, i = BCom,_0(1 + XCom)^i$$

If total allowable catch for abalone is set at Q. then:

$$Q\,\mathrm{Re}c + QCom = Q$$

and we can consider how the marginal benefits change over time through the XRec and  XCom growth factors.

If the XRec and XCom factors vary in a systematic way over time, we will get a systematic affect o the optimal allocation. For example if XCom<XRec then over time the marginal benefit of recreational use grows relative to commercial use and optimal allocation moves in the direction of the recreational sector.

This is not enough to achieve equilibrium short of the entire stock going ultimately to one sector. We need to have a feedback mechanism, whereby, as stock is allocated to a sector, the marginal benefit is reduced for further additional allocation. That is there

[8] Lindner, McLeod and Nicholls, 2005.

is a feedback effect of changes in QRec and QCom on the marginal benefit schedules of recreational and commercial fishing after a stock re-allocation adjustment.

We need to solve for this change. This is done below.

Based on Figure 1 and reflecting the study of commercial abalone in McLeod and Nicholls[9], the marginal benefit for commercial abalone use is constant so that:

$$MB_{Com} = \alpha_{com}$$

The starting value for $\alpha_{com}$ is the value from Figure 1.

Again based on Figure 1 and reflecting the contingent valuation model results for recreational abalone fishers in McLeod and Nicholls[10] the marginal benefit for recreational abalone use is non linear such that:

$$MB_{Rec} = \alpha_{rec} / (\beta_{rec} Q_{rec}{}^{2}) \text{ or}$$
$$MB_{Rec} = (\alpha_{rec} / \beta_{rec}) Q_{rec}{}^{-2}$$

The starting values for $\alpha_{rec}$ and $\beta_{rec}$ are the values in Figure 1.

Looking at a reallocation the effect is the change in Qcom and in Qrec such that;

$$-dQcom = dQrec$$

and the marginal benefits change according to;

$$dMB_{com} = 0.dQcom$$

And

$$dMB_{rec} = -2(a_{rec} / \beta_{rec}) Q_{rec}{}^{-3} dQ_{rec}$$

In applying this model we have in effect two steps.

Starting from base period zero (today) and moving to period 1 pre allocation change we have;

$$MB_{com}{}^{1} = MB_{com}{}^{0}(1 + X_{com})^{1}$$
$$MB_{rec}{}^{1} = MB_{rec}{}^{0}(1 + X_{rec})^{1}$$

Post reallocation based on the comparison between these two we would have;

$$MB_{com}{}^{1} = MB_{com}{}^{0}(1 + X_{com})^{1} - 0$$

And

[9] McLeod and Nicholls, 2004.

[10] McLeod and Nicholls, 2004.

$$MB_{rec}{}^{1} = MB_{rec}{}^{0}(1+X_{rec})^{1} - (-2(a_{rec}/\beta_{rec})Q_{rec}{}^{-3}dQ_{rec})$$

These equations can be solved for the exact allocation adjustment required in period 1 to optimize the allocation.

To do this we need to recognize that if a full static analysis has been done as the starting point we already know:

$$MBcom^{0}, MBrec^{0}, Qcom^{0}, Qrec^{0}, Q = Qcom^{0} + Qrec^{0}$$

as well as the shape (functional form) of the best fitting marginal benefit schedule.

For the analysis of abalone allocation, the values of these variables are as derived in the previous static analysis of McLeod and Nicholls[11] and are the basis for Figure 1.

In addition following the approach developed in the theoretical framework[12], we can encapsulate the various key drivers into the estimates of the growth terms;

$$Xrec, Xcom$$

This allows a solution using;

$$MB_{com}{}^{1} = MB_{com}{}^{0}(1+X_{com})^{1} - 0 = MB_{rec}{}^{1} = MB_{rec}{}^{0}(1+X_{rec})^{1} - (-2(a_{rec}/\beta_{rec})Q_{rec}{}^{-3}dQ_{rec})$$

The solution can either be based on the view that

$$MBcom^{0} = MBrec^{0}$$

meaning that we start from an initial optimal allocation or the view that;

$$MBcom^{0} \neq MBrec^{0}$$

meaning that we start from an initial sub optimal allocation.

Whichever is appropriate will depend on the results of the upfront full static analysis and an assessment of how close the starting point is to the static allocation optimum. In the case of abalone, as shown in Figure 1, the initial starting point is not a static optimum and in fact

$$MBcom^{0} < MBrec^{0}$$

This implies that allocation should be toward recreational use for abalone in period 0.

---

[11] McLeod and Nicholls, 2004.

[12] Lindner, McLeod and Nicholls, 2005.

Taking the equality view we can solve for the optimal time path of allocation as follows;

$$MB_{com}{}^{0}(1+X_{com})^{1}-\frac{\partial MB_{com}}{\partial Q_{com}}dQ_{com}=MB_{rec}{}^{0}(1+X_{rec})^{1}-\frac{\partial MB_{rec}}{\partial Q_{rec}}dQ_{rec}$$

Based on the results presented above and reflected in Figure 1;

$$\partial MB_{com}/\partial Q_{com}=0\text{, and}$$

$$\partial MB_{rec}/\partial Q_{rec}=-2(a_{rec}/\beta_{rec})Q_{rec}{}^{-3}$$

Substituting we get;

$$MB_{com}{}^{0}(1+X_{com})^{1}=MB_{rec}{}^{0}(1+X_{rec})^{1}-(-2(a_{rec}/\beta_{rec})Q_{rec}{}^{-3}dQ_{rec})$$

Solving for $dQrec$ we get;

$$dQ_{rec}=(MB_{com}{}^{0}(1+X_{com})^{1}-MB_{rec}{}^{0}(1+X_{rec})^{1})(\beta_{rec}Q_{rec}{}^{3}/2\alpha_{rec}))$$

To get $dQ_{com}$ we can use the fact that;

$$dQ_{rec}=-dQ_{com}$$

These equations allow us to project the optimal allocation in a spreadsheet optimization model for abalone allocation using simple approaches like "goal seek" or more sophisticated "solver" type models if there are side constraints such as maximum actual reallocations allowed in any one period.

The marginal benefit functions in the current study and used above are specific to the abalone fishery.

The exact functional forms have been chosen based on the detailed static analysis of the abalone fishery in the previous study by McLeod and Nicholls[13]. The coefficient estimates needed to "calibrate" the model also come from this study.

## 2.6 Calibrating the Model

To solve the model using the above equations requires that we have estimates for;

- All base level parameters and variables, namely $MBcom^{0}, MBrec^{0}, Qcom^{0}, Qrec^{0}$, and $Q=Qcom^{0}+Qrec^{0}$
- The key growth rate variables namely Xrec and Xcom.

[13] McLeod and Nicholls, 2004.

The first set of values come directly from the static allocation analysis while the second are new and must be estimated. The estimation of Xcom is taken up in Chapter 3 and Xrec is considered in Chapter 4.

# 3 Drivers of the Commercial Marginal Net Benefit Values – Finding Xcom For Abalone

## 3.1 Background

In this chapter we consider the changes the key underlying drivers that shift supply of and demand for abalone as a commercial fish species. It the balance of the changes in these drivers that influences the marginal commercial net benefit and determine the way that it changes over time. The key is to estimate Xcom in the basic model;

$$MB_{com}{}^{t} = MB_{com}{}^{0}(1 + X_{com})^{t}\text{, where}$$

- $MBcom^{t}$ is the commercial marginal net benefit in the future time period t.
- $MBcom^{0}$ is the commercial marginal net benefits determined from the application of the static model specified in previous research by McLeod and Nicholls[14]. This sets the values for the base period, period 0.
- *Xcom* is the percentage annual growth in the benefits; that is the expected annual growth in *MBcom*.

In estimating *Xcom* we need to incorporate the various drivers of commercial value and express them as annual percentage growth rates and this requires a detailed analysis of the commercial side of the fishery.

Roe's abalone is a smaller animal than the market preferred greenlip (China) and blacklip (Japan) abalone. The annual 36 tonne commercial roe abalone take from the Perth fishery is small by comparison with the 5766 tonnes of wild capture abalone in Australia. However, the income derived from this small catch is nonetheless important to seven commercial operators (and their families) who are dependent on it for their livelihood.

The roe's abalone catch from the Perth fishery is processed into canned abalone in Australia and exported rather than sold live, chilled, frozen or dried. The size of the animals taken tend to yield on average around 30 to 50 grams of meat weight, although those take from the Perth fishery tend to be at the larger end of this meat weight range. This means that, on average, meat from four to five animals taken from the Perth fishery would be required to produce a 250-gram can of exported roe's abalone.

[14] McLeod and Nicholls, 2004.

## 3.2 Overseas Markets and Export Demand Drivers

### Export Markets and Price Trends

Australia's canned abalone is mostly exported to Asian markets and sold to local abalone processors who then on sells to wholesalers in Asia. The roe's abalone catch from the Perth fishery typically produces around 11 to 12 tonnes of canned abalone meat. This represents around 1.5% of the 738 tonnes of canned abalone product exported from Australia in 2004 based on official trade statistics shown in Table 1 below.

According to these official figures, Australia's canned abalone exports were valued at almost $95 million of the $244 million of abalone product exported from Australia in that year.

The canned roe's abalone supplies a niche residual catering and institutional markets in south east Asian markets that prefer whole abalone in individual serves rather than portions of larger abalone divided up between individual serves. Unlike roe's abalone, the larger wild capture abalone at 70 gram and increasing, as minimum size restrictions in wild capture fisheries force larger greenlip and blacklip animal to be taken, are not well suited to individual serves.

As shown in Table 1, the principal markets for Australia's canned abalone exports have been Hong Kong, Taiwan, Singapore and Japan. The recent slowing in Australian canned abalone export volumes in recent years reflected the slowdown in the Japanese economy and the impact of the SARS outbreak in south east Asia on consumer confidence. This recovered recently driven by an increasing demand in China that has been met by live and frozen blacklip abalone out of Japan and by growing interest by catering trade in China in canned roe abalone.

## Table 1: Australian Abalone Exports: Calendar Years 1999 to 2005

| Product Type | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005[1] |
|---|---|---|---|---|---|---|---|
| **Product Volume** | tonnes | tonnes | tonnes | tonnes | tonnes | tonnes | tonnes |
| Live, fresh chilled | 1,155 | 1,029 | 1,331 | 1,549 | 1,578 | 1,693 | 543 |
| Frozen | 504 | 477 | 384 | 333 | 315 | 393 | 117 |
| Other | 144 | 174 | 634 | 718 | 318 | 385 | 173 |
| | | | | | | | |
| Canned[2] | | | | | | | |
| Hong Kong | 321 | 339 | 250 | 300 | 687 | 427 | 120 |
| Singapore | 181 | 158 | 90 | 135 | 185 | 114 | 36 |
| Japan | 179 | 188 | 130 | 125 | 280 | 115 | 33 |
| Taiwan | 245 | 419 | 181 | 76 | 217 | 50 | 27 |
| United States | 22 | 23 | 11 | 18 | 84 | 13 | 6 |
| Malaysia | 9 | 10 | 10 | 14 | 15 | 6 | 2 |
| China | .. | 2 | 11 | 3 | 101 | 3 | 1 |
| Canada | 3 | 1 | Nil | 2 | 9 | 6 | 2 |

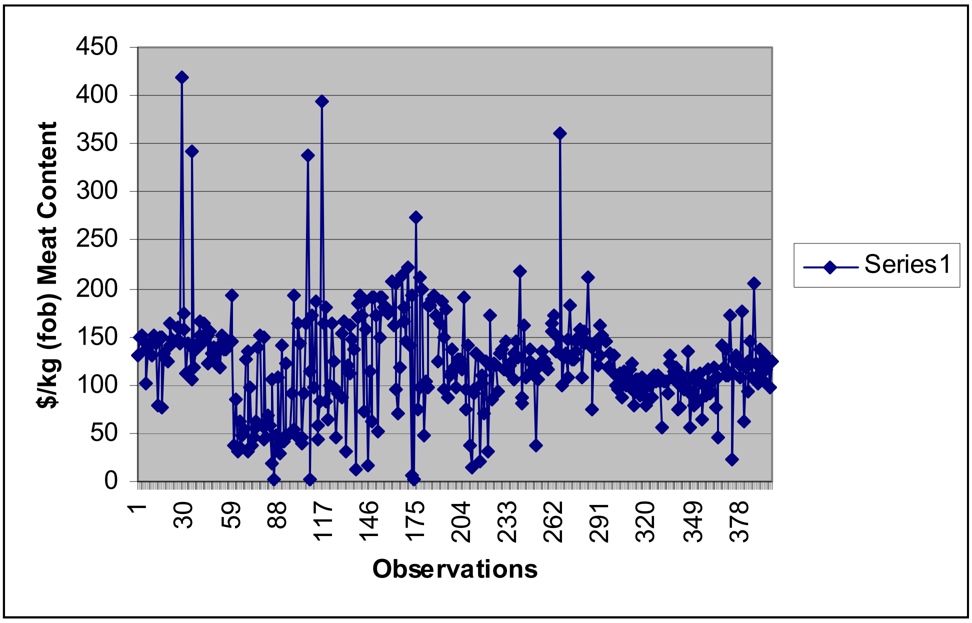
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Other | 9 | 4 | 9 | 4 | 12 | 4 | .. |
| Total Canned | 970 | 1,144 | 691 | 677 | 1,589 | 738 | 227 |
| **Total Abalone** | **2,773** | **2,824** | **3,040** | **3,277** | **3,800** | **3,209** | **1,060** |
| | | | | | | | |
| **Value (fob)** | $'000 | $'000 | $'000 | $'000 | $'000 | $'000 | $'000 |
| Live, fresh chilled | 46,698 | 55,879 | 66,110 | 80,555 | 72,872 | 80,431 | 26,718 |
| Frozen | 40,610 | 46,982 | 41,678 | 41,070 | 36,551 | 42,648 | 13,604 |
| Other | 8,895 | 13,358 | 55,592 | 57,529 | 20,989 | 25,954 | 12,834 |
| Canned | 108,754 | 129,217 | 98,039 | 62,009 | 96,540 | 94,897 | 28,860 |
| **Total** | **204,957** | **245,436** | **261,419** | **241,163** | **226,952** | **243,930** | **82.016** |

Notes: [1]4 months ending April 2005

[2] Meat content

Source: Australian Bureau of Statistics, *International Trade*, Canberra

According to official data, export values of Australian canned abalone have shown little (if any) marked upward trend over the past 15 years. These data, which are shown in Figure 2 below, show that, apart from a period of highly volatile values during 2000 to 2003, the values were highly clustered across all markets.

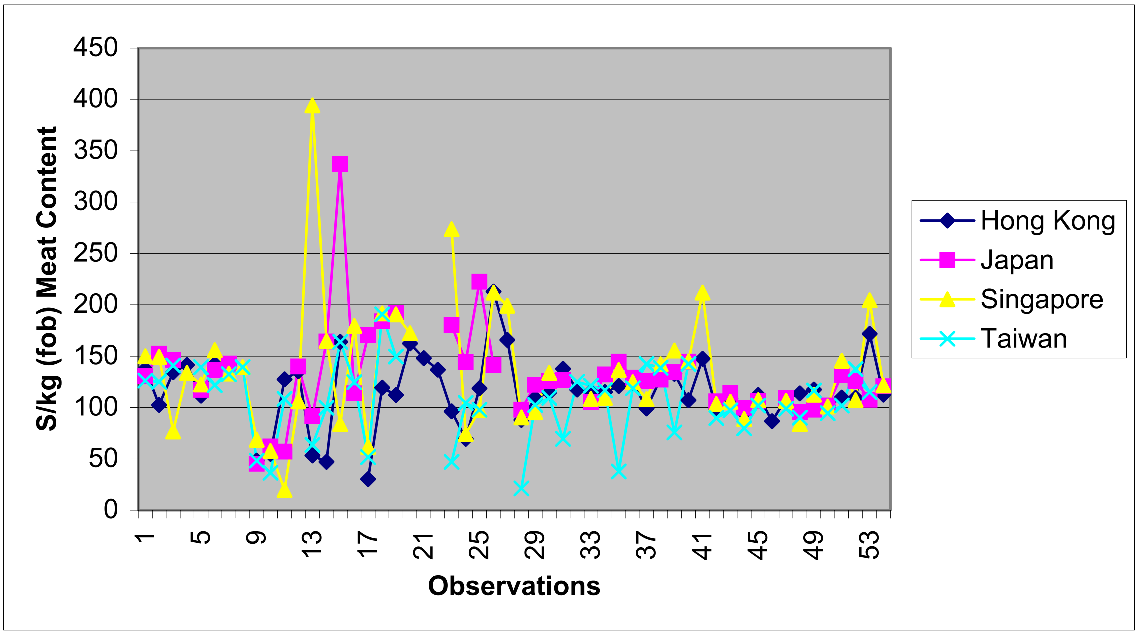



Legend: Observation 1 starts in 2005 whilst observation 378 relates to 1994

Sourced from: Australian Bureau of Statistics Data

**Figure 4: Australian Canned Abalone Export Values, 1994 to 2005**

A similar pattern and trend has been evident in the values of Australian canned abalone exports to the major markets over the same period as shown in Figure 5 below.




Legend: Observation 1 starts in 2005 whilst observation 53 occurred in 1994
Sourced from: Australian Bureau of Statistics Data

**Figure 5: Australian Canned Abalone Exports by Major Markets1994 to 2005**

These trends in past export values shown in Figure 4 and Figure 5 suggest that, over the recent past, the demand for, and supply of, abalone to world markets would appear to have been in balance. Whilst this provides an insight into what has happened in the recent past, there is a need to understand what might unfold into the future.

## Drivers of Export Demand

Export demand for Australian canned abalone will be driven largely by population growth, rising real per capita incomes, shifting product preferences and changing social demographics in south east Asian markets and competitive supplies available elsewhere. In terms of the primary markets that demand Australian canned abalone, these key drivers are shown in Table 2 below.

**Table 2: Key Drivers of Export Demand for Australian Canned Abalone**

| Market | Population Growth[1] (%) | Real Per Capita Income Growth[1] [2] (%) | Aggregate Driver (%) |
|---|---|---|---|
| Hong Kong | 0.65 | 0.69 | 1.34 |
| Taiwan | 0.64 | 0.96 | 1.60 |
| Singapore | 3.54 | 1.92 | 5.46 |
| Japan | 0.20 | 0.72 | 0.92 |
| China | 0.65 | 1.50 | 2.15 |
| Total | 0.63 | 1.44 | 2.07 |

[2]The real per capita income growth multiplied by an estimated income elasticity of demand of 0.30
Source: [1] CIA Fact Sheets

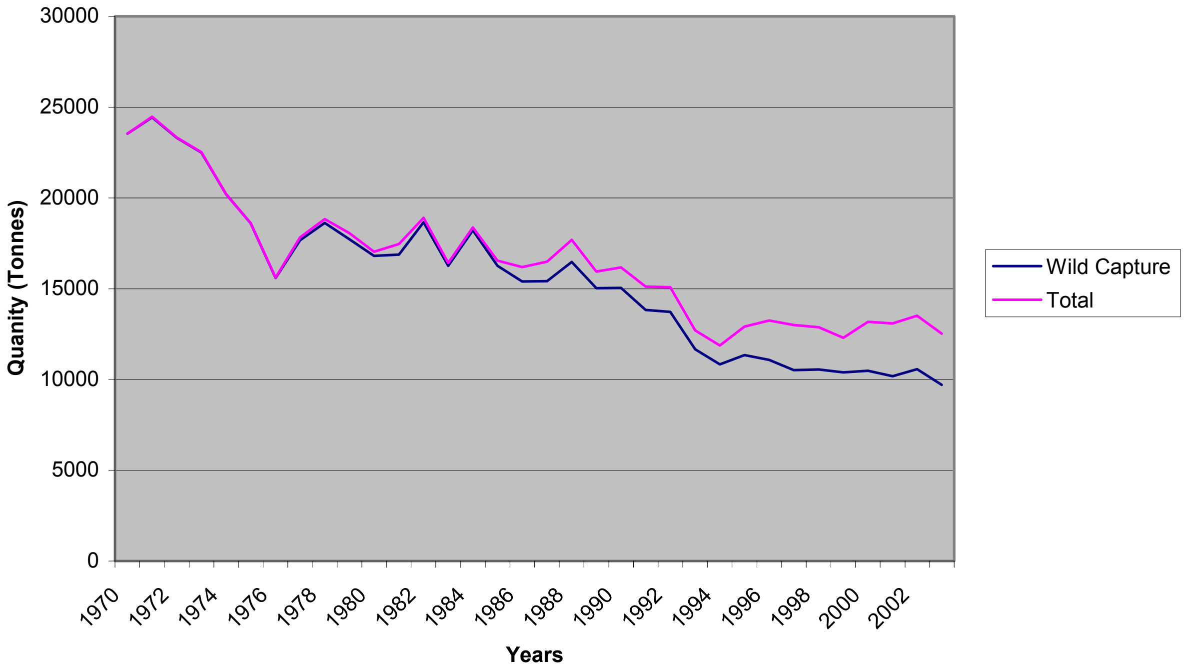
Assuming that there are no underlying shifts in tastes and preferences of consumers in south east Asian markets or changes in the underlying trends in the cross elasticity of substitution for canned roe's abalone in these market, then demand in south east Asia for Australian canned roe abalone could be growing, on average, by around 2% annually all other things remaining unchanged.

## Competitive Outlook and Risks

Estimates of world abalone production, both wild capture and cultured, differ widely. However, there is general agreement that, over the past decade, wild capture production has fallen in the main producing countries, and the increase in world cultured abalone production has done no more that offset the fall in wild capture production in recent years. (ABARE, ***e*Report** 03.8).

According to FAO production estimates, which are shown in Figure 4 below, legal catches of wild caught abalone fell from around 24,000 tonnes at the beginning of the 1970's to 10,000 tonnes by 2003[15]. Cultured abalone production rose from modest production levels of the mid-1980's to around 3000 tonnes by 2003. This is reflected by the difference between the wild capture trend line and the total trend line in Figure 6 below.

[15] In the literature there is a suggestion that the country-by-country data collected by the FAO is not standardized and understates the true quantities. Whilst this may be the case, the data have been collected on a consistent basis over time and to this extent provides a useful guide to the underlying trends in world abalone production.




Source: FAO (Electronic Data Service)

**Figure 6: World Abalone Production 1970 to 2005**

If this underlying market structure is indicative of falling aggregate supply trends in the past (even after allowing for illegal catch estimates of around 4000 to 5000 tonnes annually in recent years [16]) against the background of rising world demand as population and per capita incomes grow, then export values for Australian canned abalone export would have been expected to rise to ration the excess demand. This has not been evident in the trends in export values of Australian canned abalone exports as reflected in Figure 4 and Figure 5 . This suggests other fundamental changes are taking place in both the world demand for, and supply of, canned abalone.

## Changing Demand for Canned Abalone

Trade sources have suggested that underlying changes in the tastes and preferences are taking place in certain key Asian markets for Australian canned abalone product.

[16] Roy H Gordon and Peter Cook in a paper entitled 'World Abalone Supplies, Markets and Pricing: Historical, Current and Future Prospectives" presented to the Quingdo, China Conference (October 2003).The paper also suggests, as wild capture fisheries were subject to little, if any, regulation in the 1970's, the illegal catch was non-existent.

For instance, in the Japanese market, there is reportedly a general shift away from canned abalone product. This has been attributed to the changing social demographics of the Japanese market. Also, whilst abalone remains an essential menu item at Chinese wedding banquets, there are suggestions that declining marriage rates in Singapore, Hong Kong, and Taiwan may be impacting on the demand for abalone. It may even be that contemporary preferences may be changing among the Chinese communities in these markets.

China is seen as offering untapped market opportunities. The official export figures indicate that Australia's canned abalone export to China have not shown any marked upward trend to date. However, the trade suggests that Australian canned abalone is yet to establish a strong place in the diversity of internal markets for abalone products that exist in China where there is reportedly, at this time, a strong preference for live and canned domestically cultured abalone.

Changes in these primary demand drivers mean that the export demand in these traditional export markets may not be as strong in the future as in the past or as strong as the primary demand drivers mentioned above might suggest. Market (particularly China) and product diversification strategies are being followed by industry as a possible means to grow the export demand for Australian abalone product in the future.

### Changing Cultured Abalone Production

The growth in world cultured abalone production poses a greater risk to Australia's canned roe abalone export if the wild capture production is at the maximum sustainable take or declining and as a possible substitute product for smaller sized roe abalone. In addition to Taiwan, the Korean Republic, South Africa and Chile, cultured abalone production has occurred in China, Senegal, Mexico, and Australia in recent years.

Further cultured abalone production expansions are reportedly in the pipeline amongst these countries as well as Spain, Portugal and Ireland. World supply expansions can be expected to materialize from these investments over the next three to five years.

According to trade sources, the growing Taiwanese and Chinese cultured abalone production is targeting their respective domestic markets, whilst the expansion in Chile is directed at the United States markets. It is also claimed that the size of abalone grown out from a typical three-year aquaculture production cycle tends, on average, to be smaller in size (50mm) than those taken from the Perth abalone fishery (70mm) and to be not competitive in the established south east Asian niche markets for Australian canned roe abalone exports at the existing price differentials. However, the expansion in these supplies can place a competitive constraint on the prices differentials that can be obtained for Australian canned roe abalone as potential substitutes in consumption.

If world cultured abalone production grows faster than world demand and places downward pressures on cultured abalone prices, this could be expected to place pressure on the price differentials that can be obtained for Australian canned roe abalone in the future. However, the trade did not appear to view this as an immediate or significant risk, despite the expanded investment in cultured abalone production known to be taking place around the world, including Australia. If such competitive risks were to materialize in the medium term, the extent of that competitive pressure will depend on how strong the cross elasticity of substitution is between cultured abalone product and the canned roe abalone in these markets.

There have also been recovery and quality difficulties associated with cultured abalone production in the past. According to the trade, better animal husbandry practices, and improved handling and recovery skills can be expected to yield a better, standardized, abalone product from aquaculture over the next five to ten years. This could be expected to make the cross elasticity of substitution between the culture abalone production and canned roe abalone stronger than is presently the case, particularly if the economics of longer grow-out production cycles were to produce abalone of sizes that have meat yields similar to roe abalone.

Any likelihood of a rapid expansion in cultured abalone production in the medium term could bring with it a more immediate marketing challenge for Australian canned roe abalone to position the Australian product to mitigate any such greater competitive risk. This could for instance focus on product differentiation and product packaging, and, if that were to happen, there could be added costs of processing and marketing Australia's canned roe abalone. This could result in lower producer surpluses per unit of canned roe abalone product and reduced marginal net benefits from commercial use.

### The Net Impact of the Interaction between the Key Demand Drivers and Competitive Risks

Despite differing estimates of world abalone production, there is a general acceptance that the growth in world cultured abalone production has simply offset the reduction that has occurred in wild capture production in recent years and that this appears not to have added materially to aggregate world abalone supplies in recent time.

The past data point to fundamental changes in the underlying demand driver in the traditional Asian export markets for Australian canned abalone product. The circumstances of declining aggregate world supplies in a climate where the underlying drivers point to rising demand but export values have not shown a strong upward trend as would be expected in this market climate, indicating some negative changes in the underlying drivers of demand for canned abalone are at work in these traditional markets. These may be the result of changing taste and preferences because of social demographic changes occurring in these markets or increasing alternative product supplies like live and canned cultured abalones.

If this rate of growth in world abalone supplies exceeds the growth in world demand at existing prices, this will place downward pressure on abalone export prices. Indeed, any supply growth even when this is less than demand growth, will moderate any world price increases that might occur otherwise.

Although there is increasing investment in cultured abalone production around the world, this is apparently seen in the short term as not posing a significant risk of world abalone supplies outstripping the growth in world abalone demand nor an immediate threat to Australia's canned roe abalone exports to south east Asia. However, in the medium term, even though production uncertainties remain, the expansion in cultured abalone production from this increased investment could become a significant competitive risk for Australian canned roe abalone exports.

Taking a short-to-medium term view of the key drivers of world demand and world supply developments and setting aside short-term market fluctuations like those recently associated with a slowing Japanese economy, the chances are that discounting of Australian canned abalone export could remains a downside price risk. If world demand for Australian canned roe abalone is undergoing fundamental changes in traditional Asian export markets and if there are short term market development costs in growing the China markets, then the chances of marked rise in export prices or producer surpluses is low, particularly in the absence of the likelihood of a substantial fall in the Australian dollar in the short term.

This suggests, on the balance of probability, that, at least in the short tem, the marginal net benefits from commercial use of the Perth abalone fishery are unlikely to shift outwards markedly from those previously estimated using the static model. There is a chance that they could possibly decline marginally in the short term.

The situation in the medium term (i.e. eight to ten years) is less clear. A key driver will be the expansion in world cultured abalone production and productivity improvements in this aquaculture given the information available on the magnitude of key drivers on the demand side. These developments would need to be carefully monitored to determine if the risk profile is changing faster than expected and, if so, the impact this may be having on prices and production and marketing costs if there is a repositioning of Australian canned abalone products to mitigate any increase in the perceived competitive risks from expanding cultured abalone production. In this context, it may be helpful to establish the strength of the cross elasticity of substitution between Australia's canned roe abalone and culture abalone available at that time and the whether changes taking place in tastes and preferences in traditional Asian markets for canned abalone.

# 4 Drivers of the Recreational Marginal Net Benefit Values – Finding Xrec For Abalone

The application of the allocation model on the recreational side requires that we have an estimate of Xrec in the basic equation:

$$MB_{rec}^{t} = MB_{rec}^{0}(1 + X_{rec})^{t}$$ , where

- $MBrec^t$ is the recreational marginal net benefit in the future time period t.
- $MBrec^0$ is the recreational marginal net benefits determined from the application of the static model specified in previous research by McLeod and Nicholls[17]. This sets the values for the base period, period 0.
- Xrec is the percentage annual growth in the benefits; that is the expected annual growth in MBrec.

In estimating Xrec we need to incorporate the various drivers of recreational value as annual percentage growth rates.

Recreational abalone fishing currently has about 7000 participants, with about 18,000 licences. This means that latent effort is considerable. The 7000 is about 0.4% of the Perth adult population while at 18,000 it is 1%.

For abalone the key to the estimation of Xrec is to assess how:

- the willingness to pay will increase for the existing participants (the 7000),
- how the participation rate will increase (the new participants) and whether
- current non participating licence holders will increase their participation

In looking at these factors we can focus on some key drivers. First consider the existing fishers. We expect that their demand for abalone catch will increase as a function of:

- annual population growth. In Western Australia this is around 1.7% per annum.
- annual growth in real income per capita. In Western Australia this is about 2.5% per annum., although this may not apply to the specific abalone fishers
- income elasticity of demand for abalone recreational fishing

[17] Lindner, McLeod and Nicholls, 2005.

- change in the demographic composition of the population over time. For recreational fishing, participation rates and type of fishing appear to vary with age.
- annual percentage change in the underlying real local prices of alternative recreational activities and the cross elasticity of substitution between these alternatives and recreational abalone fishing. If prices of alternative recreational activities fall relative to the "price" of fishing then consumers will shift towards these activities and away from recreational abalone fishing.

The abalone fishery has around 7,000 active fishers and around 18,000 licence holders. There is scope for the actual participation rate to rise.

There is no evidence on the way that the participation rate may grow. For the base case zero has been assumed.

For Perth metropolitan area population is around 1.6 million so relative to population the actual participation rate is low, at less than 1%.

The overall Perth population is expected to growth at 1.7% per annum. However, it is an aging population with the 55 to 59 age group is expected to grow by 5.9% per annum and 60 to 64 age group expected to grow by 4.9% pa.

Real per capita incomes in Australia have grown by around 2.5 % per annum over the last decade and this is expected to continue for some years.

There is no data on the income elasticity for recreational abalone fishing. A value of 1.0 has been assumed, reflecting more the view that abalone is a catch primarily to eat.

Using these variables we can consider how the demand for recreational abalone fishing activity might rise.

Combining the population growth and per capita real income growth (with an income elasticity of 1) gives an overall growth in demand of 4.2% per annum.

If the participation rate increased by 1% per annum, then the overall demand growth would be 5.3%.

This is demand to catch additional animals against the current allocation of 480,000 animals. This allocation is an average of 70 animals per fisher which is less than the bag limit. If preferences were such that pressure to move to the bag limit increased, then this is an underestimate on demand growth for animals.

# 5 Making the Model Operational

The key parameters described in previous sections can be used to calibrate the allocation model. This is done using the abalone specific version of the illustrative model described in Lindner, McLeod and Nicholls[18].

Taking the model and the specific abalone functions as set out above produces a spreadsheet model solution as shown in Figure 7, Figure 8 and Figure 9 below.

The growth rates, Xrec and Xcom come from the work in Chapters 4 and 5. The marginal net benefit from commercial is based on the original study which estimated it to be $5.43 per abalone.

The value for the recreational sector was derived from the original contingent valuation study. The inverse specification from that study for willingness to pay function was used to derive a marginal willingness to pay function and to determine the way that the marginal willingness to pay changes as abalone are allocated toward the recreational sector.

The basic recreational choice equation takes the form of a logistic regression with a form:

$$Log[\frac{\Pr ob(yes)}{1-\Pr ob(yes)}] = \alpha_0 - \beta_1 FEE + \beta_2 QTY^{-1} + \sum \beta_i SOCIO$$

where FEE is the specified fee, QTY is the specified quantity, and SOCIO is set of socio demographic and attitudinal variables. In the previous analysis $\beta_1$=-.035 and $\beta_2$=-3.214.

The estimated equation can be used to determine average willingness to pay and marginal or "part worth" willingness to pay.

The marginal willingness to pay or part worth is defined in terms of the trade off between quantity and price which is of the form:

Marginal willingness to pay = $-(\partial(\Delta V)/\partial QTY)/(\partial \Delta V/\partial Fee)$,

For the inverse case this is: $(\beta_2 QTY^{-2} / \beta_1)$

In order to solve for the optimal allocation we have to allow for the fact that as stock is adjusted between sectors the relative marginal valuations change. As stock is

[18] Lindner, McLeod and Nicholls, 2005.

allocated to the recreational sector we would expect the marginal valuation of further allocations to decline, all other things equal.

In the current case study the marginal value of commercial catch is constant and, within reason, is not affected by allocation of stock to or away from the commercial sector. However, as was shown in the previous case study[19], the marginal recreational benefit of additional abalone declines rapidly when additions are measured as increases in limits. Based on the marginal willingness to pay function above, the affect of increased allocations to recreational activities is to reduce the marginal benefit from further allocations according to the equation: $(-2\beta_2 QTY^{-3} / \beta_1)$.

In the model below this is used with $\beta_1$=-.035 and $\beta_2$=-3.214 to determine the feedback affect of allocation changes involving the recreational sector.

Figure 7, Figure 8 and Figure 9 show the results when the *Xrec* is 5% per annum and *Xcom* is 2%, a 3% spread.

The analysis of commercial drivers indicates that this is a generous *Xcom* figure and various factors such as aquaculture growth suggest an even greater downward pressure on commercial values. A figure of 0% or even a negative growth is plausible. Similarly, the balance of probabilities suggests that the recreational growth may be higher than the 5% used. Migration grows faster than population overall and abalone fishing has strong ethnic/migrant focus. Older age cohorts grow even faster which may indicate increased demand. Figure 10, Figure 11, Figure 12 and Figure 13 show the allocation outcome when *Xrec* of 6% pa and *Xcom* of -1% per annum are used. Figure 11 shows the allocation share over time and Figure 12 shows the quantity adjustment required along the optimal time path.

[19] McLeod and Nicholls,2004.

| | **Assumptions** | |
|---|---|---|
| Annual Growth Rate in Recreational Net Benefits | *Xrec* | 0.05 |
| Annual Growth Rate in Commercial Net Benefits | *Xcom* | 0.02 |
| Marginal Net Benefit Recreational Catch Base Year | MB *rec,0* | 12.00 |
| Marginal Net Benefit Commercial Catch Base Year | MB *com,0* | 5.43 |
| Fish Stock to Be Allocated | Q | 768000 abalone |
| Intial Recreational Allocation | Q *rec,* 0 | 480000 abalone |
| Initial Commercial Allocation | Q *com,0* | 288000 abalone |
| Marginal Benefit Functions From Base Year Estimation | | |
| Recreational MB fucntion quantity coefficient | $\alpha_{rec}$ | -3.214 |
| Commercial MB function quantity coefficient | $\alpha_{com}$ | N/A |
| Recreational MB function price coefficient | $\beta_{rec}$ | -0.035 |
| Commercial MB function price coefficient | $\beta_{com}$ | N/A |

**Figure 7: Data Sheet For Abalone Time Path Model Scenario 1**

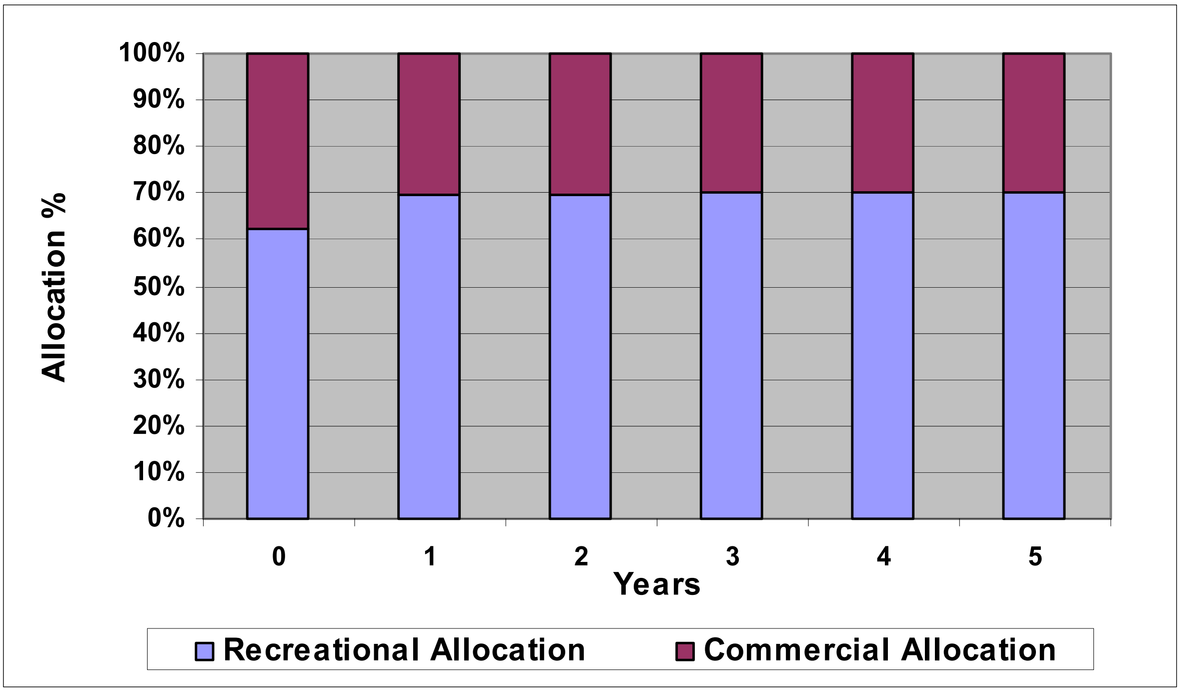



**Figure 8: Time Path of Abalone Stock Allocation for Data Sheet Assumptions Scenario 1**

| Year | 0 | Year 1 | | Year 2 | | Year 3 | | Year 4 | | Year 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj |
| Q | 768,000 | 768,000 | 768,000 | 768,000 | 768,000 | 768,000 | 768,000 | 768,000 | 768,000 | 768,000 | 768,000 |
| Q rec | 480,000 | 480,000 | 534,089 | 534,089 | 535,430 | 535,430 | 536,798 | 536,798 | 538,193 | 538,193 | 539,617 |
| Q com | 288,000 | 288,000 | 233,911 | 233,911 | 232,570 | 232,570 | 231,202 | 231,202 | 229,807 | 229,807 | 228,383 |
| MB rec,t | 12.00 | 12.00 | 5.43 | 5.70 | 5.54 | 5.82 | 5.65 | 5.93 | 5.76 | 6.05 | 5.88 |
| MB com,t | 5.43 | 5.43 | 5.43 | 5.54 | 5.54 | 5.65 | 5.65 | 5.76 | 5.76 | 5.88 | 5.88 |
| MB Diff | 6.57 | 6.57 | 0.00 | 0.16 | 0.00 | 0.17 | 0.00 | 0.17 | 0.00 | 0.17 | 0.00 |
| change in recreation allocation required to optimize allocation, year t | | | 54,089.0 | | 1,341.1 | | 1,367.9 | | 1,395.3 | | 1,423.2 |

**Figure 9: Worksheet for Optimal Time Path of Allocation Showing Annual Adjustments in Allocation of Abalone. Scenario 1**

| | Assumptions | |
|---|---|---|
| Annual Growth Rate in Recreational Net Benefits | *Xrec* | 0.06 |
| Annual Growth Rate in Commercial Net Benefits | *Xcom* | -0.01 |
| Marginal Net Benefit Recreational Catch Base Year | MB *rec,0* | 12.00 |
| Marginal Net Benefit Commercial Catch Base Year | MB *com,0* | 5.43 |
| Fish Stock to Be Allocated | Q | 768000 abalone |
| Intial Recreational Allocation | Q *rec,* 0 | 480000 abalone |
| Initial Commercial Allocation | Q *com,0* | 288000 abalone |
| Marginal Benefit Functions From Base Year Estimation | | |
| Recreational MB fucntion quantity coefficient | $\alpha_{rec}$ | -3.214 |
| Commercial MB function quantity coefficient | $\alpha_{com}$ | N/A |
| Recreational MB function price coefficient | $\beta_{rec}$ | -0.035 |
| Commercial MB function price coefficient | $\beta_{com}$ | N/A |

**Figure 10: Data Sheet For Abalone Time Path Model. - Scenario 2.**

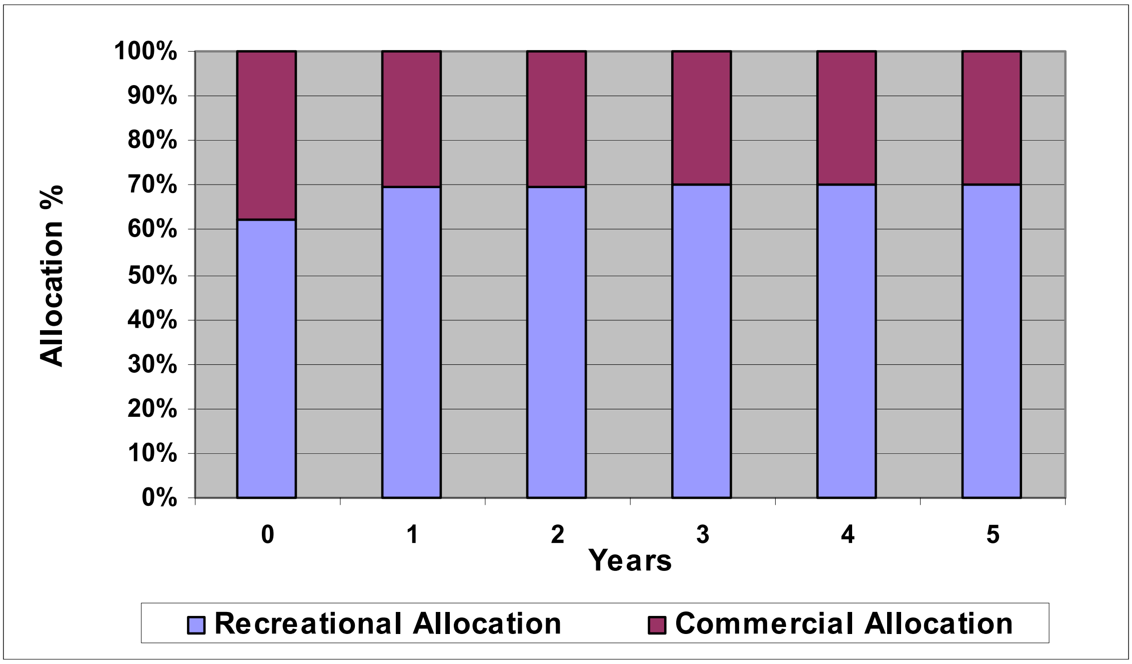



**Figure 11: Time Path of Abalone Allocation for Data Sheet Assumptions -Scenario 2.**

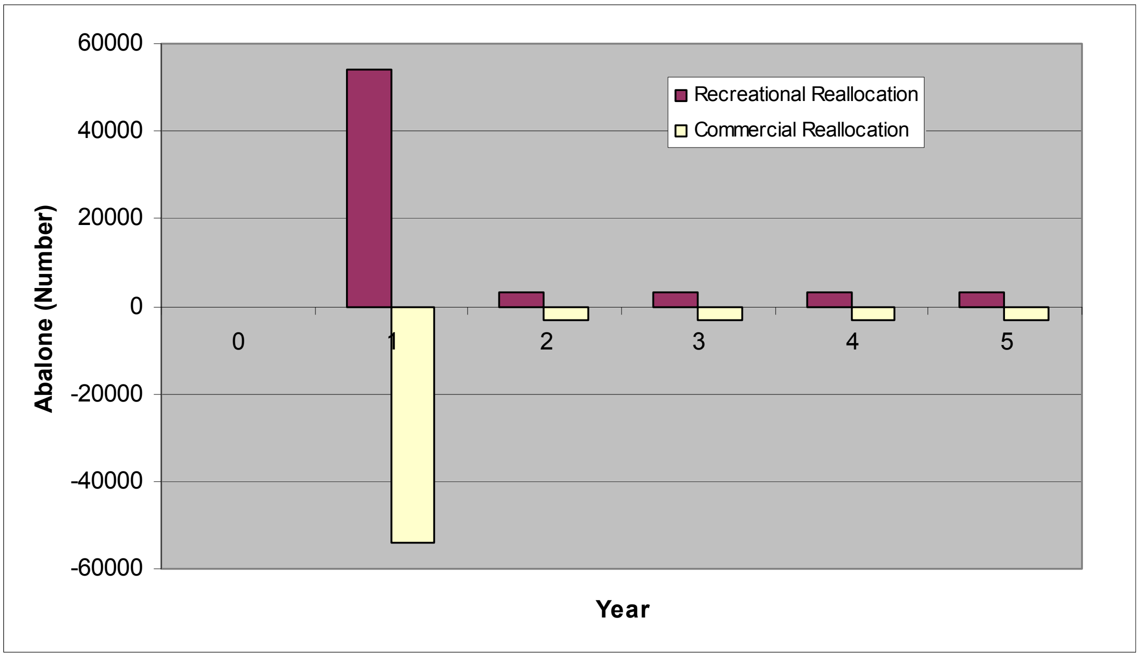



**Figure 12: Quantity Adjustment Along Time Path of Abalone Allocation for Data Sheet Assumptions -Scenario 2**

| | Year | 0 | Year 1 | | Year 2 | | Year 3 | | Year 4 | | Year 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj |
| Q | | 768,000 | 768,000 | 768,000 | 768,000 | 768,000 | 768,000 | 768,000 | 768,000 | 768,000 | 768,000 | 768,000 |
| Q rec | | 480,000 | 480,000 | 534,089 | 534,089 | 537,218 | 537,218 | 540,316 | 540,316 | 543,383 | 543,383 | 546,420 |
| Q com | | 288,000 | 288,000 | 233,911 | 233,911 | 230,782 | 230,782 | 227,684 | 227,684 | 224,617 | 224,617 | 221,580 |
| MB rec,t | | 12.00 | 12.00 | 5.43 | 5.76 | 5.38 | 5.70 | 5.32 | 5.64 | 5.27 | 5.58 | 5.22 |
| MB com,t | | 5.43 | 5.43 | 5.43 | 5.38 | 5.38 | 5.32 | 5.32 | 5.27 | 5.27 | 5.22 | 5.22 |
| MB Diff | | 6.57 | 6.57 | 0.00 | 0.38 | 0.00 | 0.38 | 0.00 | 0.37 | 0.00 | 0.37 | 0.00 |
| change in recreation allocation required to optimize allocation, year t | | | | 54,089 | | 3,129 | | 3,098 | | 3,067 | | 3,036 |

**Figure 13: Worksheet for Optimal Time Path of Allocation Showing Annual Adjustments in Allocation of Abalone. Scenario 2**

# 6 Policy Implications

The results from the application of the dynamic model to the Perth abalone fishery shown in Chapter 5 give decision makers and stakeholders an insight into the optimal allocation path over time. The model outcomes highlight the direction, extent and timing of stock re-allocations required in the future between the commercial and recreational sectors if socially optimal allocations are to be achieved and maintained.

Assuming the commercial marginal net benefits are increasing at around 2% annually (that is, Xcom = 0.02), then the dynamic model outcome for the Perth abalone fishery suggests a stock re-allocation of up to 59,618 animals annually towards the recreational sector over 5 years. These results also indicate that, once an initial re-allocation adjustment of 54,089 animals is made in year 1[20], then the re-allocation adjustments in subsequent years are small. This is because the recreational marginal net benefits fall sharply once the initial re-allocation takes place and has brought the recreational and commercial marginal valuations into line.

In practical terms, the lumpiness of any re-allocation to the recreational sector effected through any adjustment to the daily bag limit, means the re-allocation adjustment may not be able to match the required adjustment. For instance, an increase of one animal to the daily bag limit would potentially re-allocate around 45,000 animals annually by year 5. This assumes the 7000 recreational fishers that paid for and exercised the right to fish in the Perth abalone fishery in the base year increases commensurately with population growth or no change in the proportion of recreational fishers that pay for and exercise the right to recreationally fish the Perth abalone fishery.

Once this lumpy adjustment of one animal to the daily bag limit is made, further indicated reallocations are relatively minor and less than 1 animal per fisher. In these circumstances, the model could be used to indicate when the next “lump” of stock reallocation is indicated.

An appropriate course of action might be to review the allocation options and do a recalibration review of the static and dynamic models in year 6, unless monitoring of the key drivers identified in Chapters 3 and 4 highlight material changes are taking place that justify an earlier review.

In this way the model allows structured thinking about the best course of adjustments over time.

[20] This is 4,500 kilograms mentioned in the earlier research by McLeod and Nicholls (see op cit 1)

An important consideration is whether the changes are asymmetric. In this case they are in that all reallocation is towards recreational activity. With this knowledge and the estimate of the scale of the adjustment needed, the pattern of adjustment can be planned to achieve the best outcome over the five year period making due allowance for any adjustment/transaction costs.

The dynamic model is also capable of sensitivity analysis. The results show that, if the commercial net benefits were not expected to increase in the foreseeable future (that is Xcom = -1) and recreational benefits increased more (that is Xrec=.06) then the outcomes, whilst different in terms of the number of animals to be re-allocated annually by year 5 to achieve socially optimal outcomes (around 66,450 when both changes are combined), would not be sufficiently large to justify a change to allocation policy direction outlined above.

The results from the application of the dynamic model to the Perth abalone fishery assume the intra-sectoral allocations are optimal, that is the catch limits are binding on all fishers (commercial and recreational) and extra gains to either sector from an increased share of the defined sustainable catch. The previous research by McLeod and Nicholls highlighted that, whilst this was most likely the case in the commercial sector with transferable quota unit entitlement, the position was ambiguous in the recreational sector.

In a policy context, this means the intra-sectoral allocation issues in the recreational sector should be resolved first through greater choice of entitlements (e.g. days fished, and/or bag limits) before the inter-sectoral allocation options are addressed. This is because the recreational marginal net benefits can change once the intra-sectoral issues are resolved and because the recreational marginal benefit curve may not be as steeply slopping after these intra-sectoral adjustments take place.

## Appendix 1: World Abalone Production (tonnes)

| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|---|---|---|---|---|
| **Wild Capture** | | | | | | | | | |
| Australia | 5208 | 5425 | 5240 | 5247 | 5620 | 5532 | 5615 | 5809 | 5094 |
| Japan | 1980 | 1941 | 2218 | 2269 | 2109 | 2146 | 1982 | 2223 | 2182 |
| New Zealand | 1280 | 1020 | 1180 | 1300 | 1170 | 1265 | 1064 | 1090 | 1051 |
| Mexico | 1227 | 1075 | 924 | 709 | 574 | 535 | 482 | 494 | 500 |
| South Africa | 615 | 735 | 330 | 524 | 481 | 490 | 527 | 516 | 403 |
| Philippines | 483 | 448 | 183 | 347 | 282 | 241 | 288 | 292 | 310 |
| Korea, Rep.of | 260 | 188 | 214 | 71 | 79 | 113 | 104 | 75 | 94 |
| Other | 285 | 240 | 223 | 79 | 76 | 151 | 117 | 75 | 80 |
| **Total** | **11338** | **11072** | **10512** | **10546** | **10391** | **10473** | **10179** | **10574** | **9714** |
| | | | | | | | | | |
| **Aquaculture** | | | | | | | | | |
| Taiwan | 1582 | 1814 | 2208 | 2312 | 1799 | 2458 | 2496 | 2325 | 1084 |
| Korea, Rep.of | .. | 84 | .. | .. | .. | 20 | 29 | 85 | 1065 |
| South Africa | 1 | 7 | 10 | 22 | 27 | 100 | 220 | 320 | 515 |
| Chile | | 8 | 1 | 1 | 48 | 66 | 73 | 113 | 81 |
| Other | | 266 | 265 | 5 | 32 | 66 | 99 | 97 | 74 |
| **Total** | **1583** | **2179** | **2484** | **2340** | **1906** | **2710** | **2917** | **2940** | **2819** |
| **TOTAL** | **12921** | **13351** | **12996** | **12886** | **12297** | **13183** | **13096** | **13514** | **12533** |

Source: FAO (electronic data service)

ERA
ECONOMIC RESEARCH ASSOCIATES

# DYNAMIC MODELLING OF THE SOCIALLY OPTIMAL ALLOCATION OF FISH RESOURCES BETWEEN COMMERCIAL AND RECREATIONAL USE

## (FRDC Project 2003/039)

# PART FOUR

# WEST COAST WETLINE FISHERY CASE STUDY

**By R Lindner, P McLeod and J Nicholls**

# FOREWORD

The West Coast 'Wetline' Fishery is one of three case studies used to calibrate a dynamic model for evaluating allocation options for fish stocks between recreational and commercial fishing. The basic model was outlined in Part A of this research project.

This project builds on previous FRDC-funded research by Hundloe, *et al* and by McLeod and Nicholls. The McLeod and Nicholls research (FRDC project 2001/065) was designed to provide fisheries managers and stakeholders with a framework and methodology to estimate and compare marginal values of fish caught by the commercial and recreational sectors on a sound and consistent basis.

The original research focused on demonstrating the application of the general theoretical framework and methodologies for a single period, static, model in three case study fisheries – Perth Abalone, Cockburn Sound Crab and the West Coast Wetline Fishery. The case studies fisheries for the dynamic modeling are the same as those used by McLeod and Nicholls in their previous research.

Therefore this West Coast 'Wetline' Fishery case study uses and builds on the methodology and results contained in the earlier case study.

As a result of this and the earlier research mentioned above, fisheries managers and stakeholders have access:

- To a clear explanation of the appropriate conceptual framework for resource allocation decisions; and
- To sound and consistent guidelines for applying suitable tools to estimate comparable values for evaluating resource allocation between competing uses and for determining the socially optimal allocation path for fish stock.

Whilst this research focused on recreational and commercial uses, the conceptual framework and valuation methodologies and models are capable of being applied to evaluate a wider set of allocation options (passive and non-passive) for a fish resource.

**Economic Research Associates**

**August 2006**

## TABLES AND FIGURES

# 1. INTRODUCTION

## 1.1 Background

The West Coast 'Wetline' fishery is one of three case studies designed to provide practical guidance to fisheries management and stakeholders in the application of the general theoretical framework and dynamic modelling tool to address the socially optimal allocation path of fish stocks between the commercial and recreational fishing sectors.

Earlier research by McLeod and Nicholls[1] provided a conceptual framework and methodological tools for estimating the appropriate marginal values for recreational and commercial fishing at a point in time on a sound and consistent basis and for determining the socially optimal allocation at that point in time. This was applied to the West Coast 'wetline' fishery, where there are intensifying resource sharing pressures between commercial and recreational use, to demonstrate the application of this theoretical framework and associated static allocation model.

Whilst a multi-species fishery, the case study concentrates on commercial and recreational line fishing for pink snapper, dhufish and balchin groper. These three demersal species, which are the most sought after by both the commercial and recreational sector in the West Coast fishery, are generally found off shore. This typically requires access by boat even for recreational fishers. Jetty or shore based catches of these three sought after species are insignificant.

The West Coast 'Wetline' fishery case study results provided a benchmark of the marginal values of commercial and recreational use and socially optimal allocation in the fishery at a point in time. However, whilst it is critical to identify socially optimal allocations at a given point in time, it is equally important to recognize that this optimal allocation is likely to change over time.

The results from the previous static analysis highlighted the need to understand not just the marginal values that commercial and recreational uses generate for fish stocks but how these values are likely to change over time, the underlying determinants of these changes in relative values and how these changes impact on the socially optimal allocation in the future.

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[1] McLeod , P and Nicholls, J . 'A Socio-Economic Valuation of Resource Allocation Options between Commercial and Recreational Sectors: Part IV The Western Australian Wetline Fishery Case Study' FRDC Project 2001/065. FRDC: Canberra. 2004.

Whilst the static analysis gives fisheries management a well defined framework for assessing allocation at a point in time, decision makers around Australia considered that there would be value in further analysis that looked at a dynamic model capable of modelling the impact of changes in key drivers on commercial and recreational relative values over time, and on consequential changes in the socially optimal allocation through time.

The basic theory of the dynamic analysis was developed in Lindner, McLeod and Nicholls[2]. The current study develops a dynamic model that can be used to consider the way that relative marginal values may change over time and how this may affect the optimal resource allocation for the three fish species taken from the West Coast 'Wetline' fishery that are most sought after by the both commercial and recreational sectors.

## 1.2 The Report Structure

Chapter 2 briefly looks at the fishery and revisits the outcomes from the application of the basic static allocation model to the West Coast 'Wetline' fishery. It describes what is needed to develop the dynamic allocation model for the fishery. Chapter 3 looks at the marginal net benefits from commercial catch and the key drivers that cause the marginal commercial values to change over time. Chapter 4 looks at the marginal net benefits from recreational catch and the key drivers that change these marginal net benefits over time. Chapter 5 puts these into a dynamic framework that allows the direction of the change in the socially optimum allocation of the three key 'wetline' species through time to be estimated, whilst Chapter 6 discusses the policy implications of these outcomes.

[2] Lindner, R, McLeod, P and Nicholls, J. Dynamic Modelling of Socially Optimal Resource Allocation, Part A, A General Theoretical Framework. FRDC Project 2003/039. FRDC: Canberra. 2005

# 2 Overview of West Coast 'Wetline' Fishery, Static and Dynamic Allocation Models

## 2.1 Management Regime in the West Coast 'Wetline' Fishery

The multi-species West Coast Wetline fishery in Western Australia corresponds to the West Coast bioregion and stretches 1100 kilometres from Augusta in the South West to Kalbarri in the North of the State. However, this study concentrates on three species most sought after by both commercial and recreational fishers in this fishery, that is, pink snapper, dhufish and balchin groper.

The West Coast fishery is often referred to as an 'open access' fishery where there is no explicitly defined total sustainable take for either sector or in aggregate. Whilst commercial entry is limited to 1350 unit holdings with a West Coast 'wetline' fishing license, there is considerable latent effort with only around 240 of these total number of commercial unit holdings typically being exercised in any year. Also, there is potential for increasing recreational participation in the fishery from population and tourism growth. Technological advancement over the past 10 years in the form of GPS and sounders are likely to have had a significant impact on the catching efficiency of both sectors.

Recreational catches of the three species are part of a wider daily bag limit of fish species applying in this fishery, although the bag limit catches of any of the three sought after species are seldom realized. There are also legal minimum sizes for retained catches of the three species that are the same for both sectors, whilst commercial fishing is limited to hand and long lines.

The reported annual commercial catch of all three species was estimated by the Fisheries Department to be around 504 tonnes in total at the time of the earlier research by McLeod and Nicholls[3], whilst the recreational take was estimated to be around 350 tonnes in 2001/02.

## 2.2 Original Static Model Results

The 'Wetline' fishery raises some complex issues regarding the analysis of allocation and in the application of the general theoretical framework to the fishery.

The fishery is effectively 'open access' as the license limitations on commercial fishing units and the daily bag limit restrictions on recreational fishers are non-binding. In the circumstances, both commercial and recreational fishers can easily

[3] op cit 1

increase effort (e.g. more commercial fishing units exercising entitlements to participate in the fishery, increased fishing trips by commercial and recreational fishers and increased time spent on each fishing trip) with the result that they can seek more catch without any commensurate change in explicitly defined allocations.

If commercial fishers reduced actual (not latent) effort in the fishery, commercial catches may fall. These fish would be available to be hunted by recreational fishers. However, there is no guarantee that all or any of a reduced commercial catch would be caught by recreational fishers.

On the other hand, if recreational fishers' daily bag limits relating to these species were reduced, in circumstances where actual catch experience is well below the bag limits, there may be little (if any) change in actual recreational catches. Hence, there may be little change in the availability of additional fish for commercial fishers to catch.

Consequently, there is no fixed aggregate or individual species catch to be shared. This conflicts with the key assumption of the basic allocation model that an actual aggregate catch is defined and that, at the margin, competing users (recreational and commercial fishers) are playing a zero sum game - a fish caught/not caught by one would be not caught/caught by the other in a simple and straightforward way. These circumstances result in a situation where there is no simple way to reallocate fish between the fishers in the Wetline fishery.

For the demonstration purposes of the previous case study by McLeod and Nicholls, they assumed:

- the existing combined commercial and recreational effort in the West Coast 'wetline' fishery to be sustainable; and
- the existing commercial (504 tonnes) and recreational (350 tonnes) catches of the case study species to be the total sustainable catch (850 tonnes).

The resource allocation options between the two sectors were analysed within this total catch scenario.

The static analysis also assumed any explicit increase or reduction in either commercial or recreational catch of these fish species would result in an immediate and commensurate catch reduction or increase by the other unaffected sector. While neither of these outcomes may be exactly the case in practice, these assumptions were considered to represent reasonable starting points for thinking about allocation issues in the fishery.

The marginal net benefits for the recreational sector reflected not just use values. A significant element of the marginal net benefit for the recreational sector was attributable to experiential and options values unlike the circumstances in the two previous case studies where use values were dominant. The commercial net benefits as with the two previous case studies reflected use values in local consumption. The results of the previous McLeod and Nicholls analysis are shown in Figure 1 below.

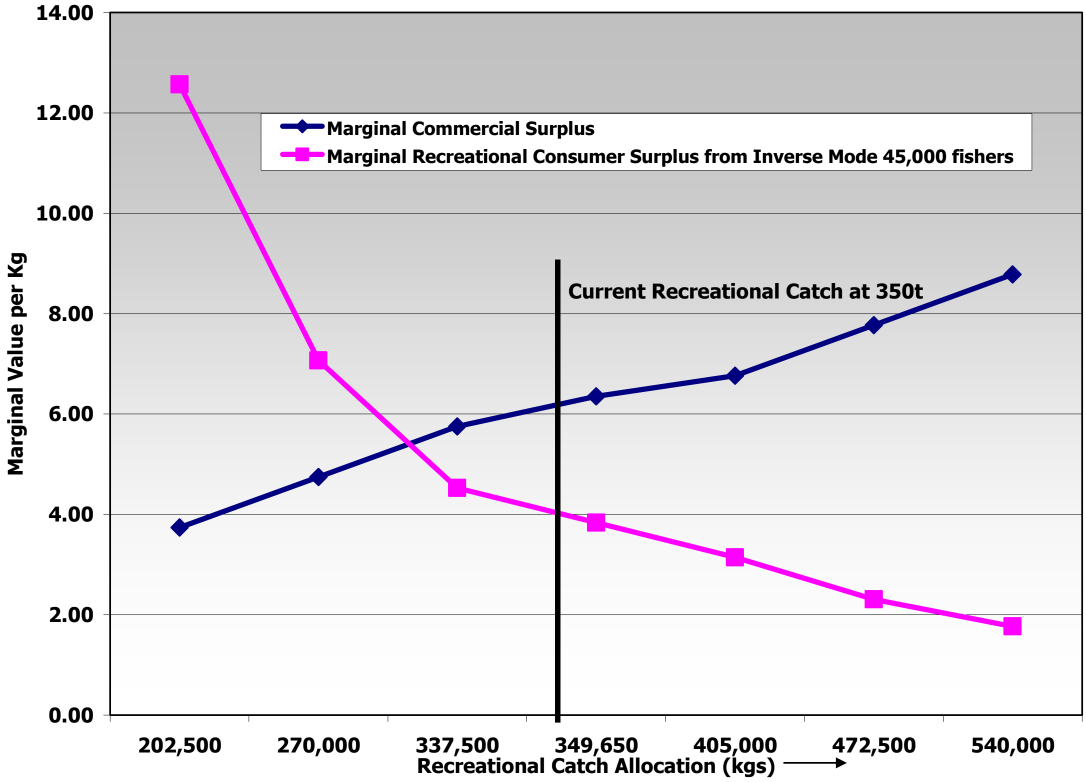


**Figure 1: Marginal Net Benefits of Commercial and Recreational Use for the Combined Take of the Three Key Species Taken from the West Coast 'Wetline' Fishery**

The results show that, at the existing allocations between the two sectors, the marginal net benefits of an extra fish allocated to commercial use exceeded the marginal net benefits of that fish to the recreational sector. This suggested that an extra fish re-allocated away from the recreational sector to the commercial sector would increase the overall net benefit to society from the use of these fish resources.

Indeed, as shown in Figure 1, the theoretically optimal shares would be around 310 tonnes retained recreational catch and 540 tonnes commercial take in aggregate for the three case study species at the present time. At this point, the marginal benefit from commercial and recreational use is the same, that is, around $5.50 per kilogram of whole fish. This would mean a reduced recreational share of up to 40 tonnes of fish from the recreational sector. These results are highly sensitive to the assumptions made about the number of recreational participants in the West Coast 'Wetline' fishery.

The modelling shows that this reduced level of retained recreational take of around 2.3 fish per person of the case study species (assuming 45,000 recreational participants in the fishery and 3 kg average weight for the basket of retained case study species catch). This is marginally less then the existing average recreational take of 2.66 fish during 2001-2002. In practical terms the analysis suggests that the gains in attempting to 'fine tune' the actual retained recreational catch from 2.66 to 2.3 fish per person would be problematic in the current fisheries management environment.

The gain in the overall benefits from the combined commercial and recreational use would be up to $76,000 (assuming no transaction costs) to an estimated $6.6 million for the existing catch shares. In reality, the net gains are likely to be less than this given transaction costs of enforcing reduced recreational catch limits. In consequence, there was unlikely to be any material net gain in reallocating existing actual catch shares at the that point in time.

The McLeod and Nicholls[4] results suggested that the values that recreational fishers would ascribe an extra retained catch of the case study species where there was a greater degree of catch certainty may be higher than these outcomes. However, in this fishery, the reallocation may need to be quite 'lumpy' if there were to be any significant lowering in the probability of an increased recreational catch of the case study species.

The species and size composition of the recreational basket that might optimise the marginal net benefits could not be determined from the recreational data available. However, there may be net benefit gains in differentiating the size of the fish that can be retained by commercial and recreational fishers if the existing management rules remain.

### 2.2.1 .Underlying Assumptions for Applying Optimal Resource Sharing Models

This analysis is based on certain assumptions. It assumes that:

- The combined existing commercial and recreational catch is all that is sustainable and available for inter-sectoral allocation,
- All recreational participants are subject to binding constraints (catch limits), that is, there is no unused or spare capacity,

[4] Op cit 1

- For all commercial operators it is optimal to take the total sustainable catch, that is, there is no spare capacity, and
- All commercial operators are internally structured to maximize producer surpluses from catches of the case study species in the West Coast' Wetline' fishery

There is currently ambiguity around the total sustainable catch in this fishery. Also, the results of our analysis indicate that the assumptions relating to the commercial and recreational activity do not hold.

In what is effectively an 'open access' fishery, the immediate issue is a sustainable catch not resource allocation. Both commercial and recreational fishers can increase effort to achieve increased catch without any commensurate and explicit change in catches allocations.

## 2.3 Applying the Dynamic Model to West Coast 'Wetline' Fishery

The starting point for the application of the dynamic model is the dynamic framework developed in Lindner, McLeod and Nicholls[5] and the static model marginal values and optimal allocation results from the previous study by McLeod and Nicholls[6].

In essence, we have to take the marginal net benefit functions based on the assumptions mentioned in Section 2.2 above and shown in Figure 1 and fit them into the dynamic framework shown in Figure 2 and Figure 3 below for the wetline fishery where this combines the three sought after species (i.e. pink snapper, dhufish and balchin groper).

[5] op cit 2

[6] op cit 1

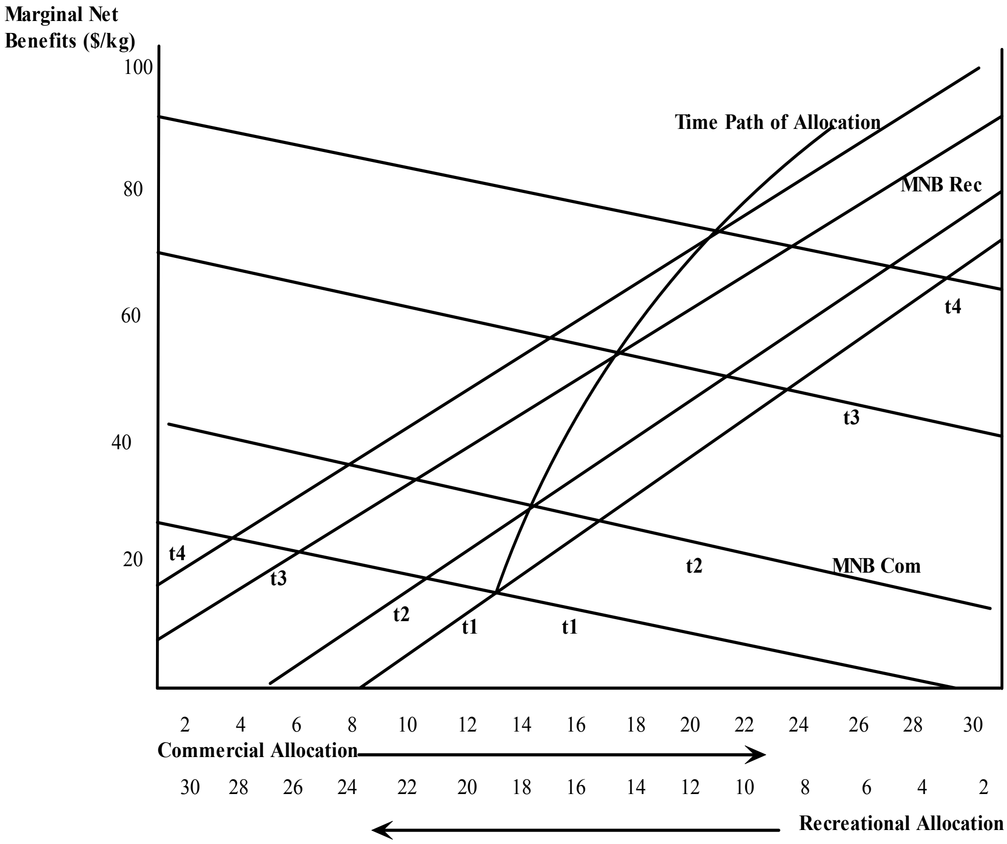


**Figure 2 : Optimal Time Path of Allocation When Shift is Toward Commercial Use of the Three Key Species Taken from the West Coast Wetline Fishery**

In Figure 2, the time path of allocation moves toward commercial sector over the four time periods t1 to t4. In Figure 3 the allocation time path moves toward recreational sector in each of the four time periods.

These diagrams assume that we start from the optimal initial allocation such as that shown for the fishery in Figure 1 above. However, in Figure 1, the optimal allocation requires an adjustment toward commercial use to achieve an initial optimal allocation at the existing catch levels. The existing allocation was therefore sub-optimal in the current environment and the dynamic model needs to cope with this.

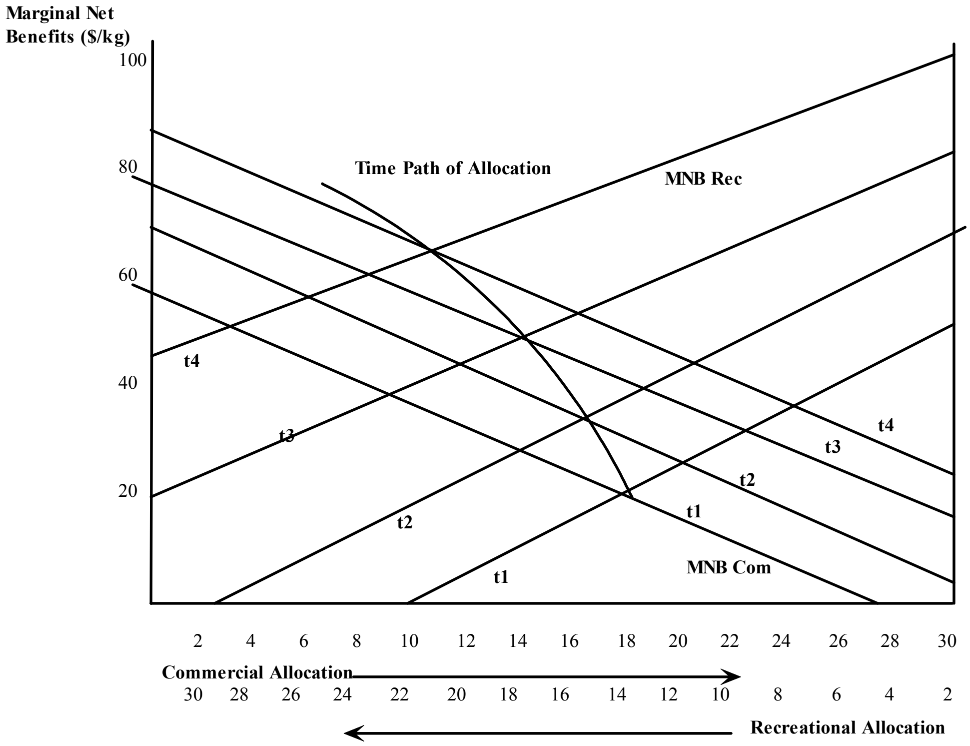


**Figure 3 : Optimal Time Path of Allocation When Shift is Toward the Recreational Use of the Three Key Species Taken from the West Coast Wetline Fishery**

The application of the dynamic model is based on identifying the key variables that affect commercial and recreational values over time, and the way they will change relative to each other over time. That is, it is based on formulating relationships that determine how the commercial and recreational marginal valuation schedules shown in Figure 2 and Figure 3 change over time for each of the three sought after species.

The variables that will shift these relationships include demography, biology, technical change (including aquaculture developments), and underlying economic drivers and related market conditions.

The dynamic model is not designed to specify precise optimal allocation solutions at future points in time in terms of exact quanta for the West Coast 'Wetline' fishery.

Rather it will help fisheries managers and stakeholders to make informed stock re-allocation decisions today in the knowledge of the likely future trends in the relevant values relative to commercial and recreational fishing for pink snapper, dhufish and balchin groper and the implications of the trends in these values for the likely direction of optimal stock allocation of each of these species tomorrow. The analysis is based on the notion of a total allowable catch that will be in existence over time and which is to be allocated optimally between the commercial and recreational sectors in a zero sum game framework

An important outcome of dynamic modelling is that it will enable formulation of a smooth allocation path over time (with typically five to ten year timeframes) that is consistent with longer run economic, biological, demographic and other social trends shifting the relative benefits of commercial and recreational use through time. This will enable fisheries managers to take a more strategic approach to resource allocation for the West Coast 'wetline' fishery by providing them with a practical interpretative tool that can forecast the direction of appropriate future fish stock allocations.

## 2.4 The Dynamic Model for West Coast 'Wetline' Fishery

In developing the basic framework for analysing the path of likely allocation adjustments over time, the logical starting point is to consider the relationships that lie behind the marginal net benefit schedules for commercial and recreational fishing. There are two parts to this. First, we need a framework for each marginal net benefit schedule that will enable us to understand and analyse the way that key variables influence changes in marginal net benefits. Second, we need a relatively straightforward framework or model that will allow us to calibrate the key relationships and shape of the time path of allocation adjustment over time.

The first fits neatly within the conventional demand and supply framework and the drivers are variables that shift the relevant demand and supply curves. The second matches well with those policy evaluation models in economics, which focus on relative growth rates for net benefits as part of benefit cost analysis. This is the approach that is considered in the next section.

## 2.5 Mathematical Model of Optimal Allocation Time Path for West Coast 'Wetline' Fishery

In order to develop a decision making approach to allocation in future periods we need to translate the thinking from the previous sections into a formulation of the optimal time path of allocation. The starting point is the static model and associated optimal allocation and marginal values as reflected in Figure 1.

For the sought after species in the West Coast fishery, the commercial marginal net benefit is a diminishing function of catch. That is, the marginal net commercial benefit per kg reduces as the quantum of the fish allocated to commercial use increases.[7] The analysis was based on surveys or catching and retail activities.

The recreational marginal net benefit schedule is derived from the logistic choice model that was estimated in McLeod and Nicholls[8]. This was based on a contingent survey of recreational boat users, which focused on their marginal willingness to pay for additional daily bag limits.

From any starting point there are in fact an infinitive number of allocation paths. Ideally, we would choose the one that maximized the value of the stream of benefits (the sum of commercial and recreational net benefits) over time. The economic approach to this is to maximize the net present value of this benefit stream for each of the sought after species from the West Coast 'Wetline' fishery as shown in the following equation.

$$NPV_{TP} = \sum_{i=1}^{i=n} \frac{B\mathrm{Re}c,i + BCom,i}{(1+r)^i}$$

If we maximize the NPV, subject to the absolute total allowable catch we will be selecting the optimal time path of allocation of the catch between the recreational and commercial sectors and maximizing the social value of the fishery. We assume the sustainable catch to be allocated over time is as mentioned above and that this is fixed for the purposes of applying the dynamic modelling. At any point in time the optimal allocation occurs where:

.

$$MNB\mathrm{Re}c = MNBCom$$

Under this assumption no upfront adjustment is needed to the allocation. We just need to keep the equality in place over time by adjusting the allocation. To do this requires that we forecast the commercial and recreational marginal benefit value for each future year and solve for the allocation that equates the forecast recreational and commercial marginal benefits.

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[7] The marginal commercial net benefit captures both consumer surplus and producer surplus associated with commercial harvest and consumption.

[8] Op cit 1

Based on the general dynamic model developed in Lindner, McLeod and Nicholls[9], we begin with the fully documented base values for the three sought after species for both commercial and recreational use.

For the recreational sector the base value is assumed to grow (decline) according to the relationship:

$$B\mathrm{Re}c,i = B\mathrm{Re}c,_0(1 + X\,\mathrm{Re}c)^i$$

For the commercial sector the base value is assumed to grow (decline) according to the relationship:

$$BCom,i = BCom,_0(1 + XCom)^i$$

If total allowable catch for these fish is set at Q. then:

$$Q\,\mathrm{Re}c + QCom = Q$$

and we can consider how the marginal benefits change over time through the XRec and XCom growth factors.

If the XRec and XCom factors vary in a systematic way over time, we will get a systematic affect on the optimal allocation. For example, if Xcom < Xrec, then over time the marginal benefit of recreational use grows relative to commercial use and optimal allocation moves in the direction of the recreational sector.

This is not enough to achieve equilibrium short of the entire stock going ultimately to one sector. We need to have a feedback mechanism whereby, as stock is allocated to a sector, the marginal benefit is reduced for further additional allocation. That is, there is a feedback effect of changes in Q*rec* and Q*com* on the marginal benefits of recreational and commercial fishing activity after a stock re-allocation adjustment.

Based on the theory underpinning Figure 1 and reflecting the results for commercial wetline fishing in McLeod and Nicholls[10], the marginal benefit for commercial use of the three key species taken from the West Coast fishery is diminishing value. Using a linear form we get:

$$MB_{Com} = \gamma_{com} - \alpha_{com}Q_{com}$$

$\gamma_{com}$ is a constant and $\alpha_{com}$ is the coefficient derived from a linear regression fitted to the marginal commercial benefit data shown in Figure 1.

[9] op cit 2

[10] op cit 1

The marginal benefit for recreational use is based on the contingent valuation model results for recreational wetline fishers in McLeod and Nicholls[11]. The best fitting equation was an inverse specification (see below) which means that:

$$MB_{\mathrm{Re}\,c} = \alpha_{rec} / (\beta_{rec} Q_{rec}{}^{2}) \text{ or}$$
$$MB_{\mathrm{Re}\,c} = (\alpha_{rec} / \beta_{rec}) Q_{rec}{}^{-2}$$

The values for $\alpha_{rec}$ and $\beta_{rec}$ are the values from the estimated logistic choice model.

Looking at a re-allocation the effect is to change Q*com* and Q*rec* such that:

$$-dQcom = dQrec$$

and the marginal benefits change according to:

$$dMB_{com} = -\alpha_{com}.dQ_{com}$$

And

$$dMB_{rec} = -2(a_{rec} / \beta_{rec}) Q_{rec}{}^{-3} dQ_{rec}$$

In applying this model we have in effect two steps.

Starting from base period zero (today) and moving to period 1 pre allocation change we have:

$$MB_{com}{}^{1} = MB_{com}{}^{0} (1 + X_{com})^{1}$$
$$MB_{rec}{}^{1} = MB_{rec}{}^{0} (1 + X_{rec})^{1}$$

Post reallocation based on the comparison between these two we would have:

$$MB_{com}{}^{1} = MB_{com}{}^{0} (1 + X_{com})^{1} - \alpha_{com} dQ_{com}$$

And

$$MB_{rec}{}^{1} = MB_{rec}{}^{0} (1 + X_{rec})^{1} - (-2(a_{rec} / \beta_{rec}) Q_{rec}{}^{-3} dQ_{rec})$$

These equations can be solved for the exact allocation adjustment required in period 1 to optimize the allocation.

To do this we need to recognize that, if a full static analysis has been done as the starting point, we already know:

$$MBcom^{0}, MBrec^{0}, Qcom^{0}, Qrec^{0}, Q = Qcom^{0} + Qrec^{0}$$

as well as the shape (functional form) of the best fitting marginal benefit schedules.

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[11] op cit 1

For the analysis of the allocation of the three sought after species in the West Coast fishery, the values of these variables is as derived in the previous static analysis of McLeod and Nicholls[12].

In addition following the approach developed in the theoretical framework[13], we can encapsulate the various key drivers into the estimates of the growth terms:

$$Xrec, Xcom$$

This allows a solution using:

$$MB_{com}{}^{1} = MB_{com}{}^{0}(1 + X_{com})^{1} - \alpha_{com} dQ_{com} = MB_{rec}{}^{1} = MB_{rec}{}^{0}(1 + X_{rec})^{1} - (-2(a_{rec} / \beta_{rec})Q_{rec}{}^{-3} dQ_{rec})$$

The solution can either be based on the view that

$$MBcom^{0} = MBrec^{0}$$

meaning that we start from an initial optimal allocation or the view that:

$$MBcom^{0} \neq MBrec^{0}$$

meaning that we start from an initial sub optimal allocation.

Whichever is appropriate will depend on the results of the upfront full static analysis and an assessment of how close the starting point is to the static allocation optimum. In the case of the three key species taken from the West Coast fishery, as shown in Figure 1, the initial starting point is not a static optimum and in fact

$$MBcom^{0} > MBrec^{0}$$

This implies that the initial adjustment toward optimal allocation should be toward greater commercial use for the three sought after species from the West Coast 'Wetline' fishery in period 0.

Taking the equality view we can solve for the optimal time path of allocation as follows;

[12] op cit 1

[13] op cit 2

$$MB_{com}{}^{0}(1+X_{com})^{1}+\frac{\partial MB_{com}}{\partial Q_{com}}dQ_{com}=MB_{rec}{}^{0}(1+X_{rec})^{1}+\frac{\partial MB_{rec}}{\partial Q_{rec}}dQ_{rec}$$

Based on the analysis presented above,

$$\partial MB_{com}/\partial Q_{com} = -\alpha_{com}\text{, and}$$

$$\partial MB_{rec}/\partial Q_{rec} = -2(a_{rec}/\beta_{rec})Q_{rec}{}^{-3}$$

Substituting we get;

$$MB_{com}{}^{0}(1+X_{com})^{1}-\alpha_{com}dQ_{com}=MB_{rec}{}^{0}(1+X_{rec})^{1}-2(a_{rec}/\beta_{rec})Q_{rec}{}^{-3}dQ_{rec}$$

Solving for $dQcom$ we get;

$$dQ_{com}=\frac{(MB_{rec}{}^{0}(1+X_{rec})^{1}-MB_{com}{}^{0}(1+X_{com})^{1})}{-\alpha_{com}-2(a_{rec}/\beta_{rec})Q_{rec}{}^{-3}}$$

To get $dQ_{rec}$ we can use the fact that;

$$dQ_{rec}=-dQ_{com}$$

These equations allow us to project the optimal allocation in a spreadsheet optimization model for the allocation of the three sought after species from the West Coast 'Wetline' fishery using simple approaches like "goal seek" or more sophisticated "solver" type models if there are side constraints such as maximum actual reallocations allowed in any one period.

The marginal benefit functions in the current study and used above are specific to the Wetline fishery.

The exact functional forms have been chosen based on the detailed static analysis of the West Coast 'wetline' fishery in the previous study by McLeod and Nicholls[14]. The coefficient estimates needed to "calibrate" the model also come from this study.

## 2.6 Calibrating the Model

To solve the model using the above equations requires that we have estimates for:

- All base level parameters and variables, namely $MBcom^{0}, MBrec^{0}, Qcom^{0}, Qrec^{0}$, and $Q = Qcom^{0} + Qrec^{0}$
- The key growth rate variables namely Xrec and Xcom.

[14] op cit 1

The first set of values come directly from the static allocation analysis, while the second are new and must be estimated. The estimation of Xcom is taken up in Chapter 3 and Xrec is considered in Chapter 4. The results from the dynamic modeling are presented in Chapter 5.

# 3 Drivers of the Commercial Marginal Net Benefit Values – Finding Xcom For the Three Key Fish Species Taken from the West Coast 'Wetline' Fishery

## 3.1 Background

Historically, the commercial catch in this fishery fluctuates from year to year. As mentioned in the earlier McLeod and Nicholls report[15], the commercial take of case study species from the West Coast 'Wetline' fishery is predominantly sold for consumption in Western Australia.

Exports (largely inter-State and occasionally overseas) typically average, around 10 to 15 per cent of the commercial catch of each of the case study species in recent times. These tend to be residual markets where the proportion of the local catch sent to export can rise or fall depending on the net returns available from Eastern States markets at the time.

Consequently, the net benefits from commercial use reflect:

- the aggregate 'producer surpluses' of harvest and post harvest activities in Western Australia associated with the local and export market disposals of the case study species taken from the West Coast 'Wetline' fishery; plus
- the local 'consumer surpluses' associated with local market disposals of the case study species taken from the fishery.

## 3.2 Applying the Dynamic Model in a Multi-Species Fishery

Theoretically, the absolute net benefit values and the Xcom growth factors can be different for each of the three sought after species. As shown in the earlier McLeod and Nicholls report, the net benefit values for commercial use differed among these three species.

However, whilst it is important to determine these individual net benefits values and growth factors, the outcomes from the application of the dynamic allocation model are dependent on:

- the net benefit relativities among the species and not the absolute levels; and
- the Xcom growth factor relativities among the species and not the absolute magnitudes of these growth factors, that is, whether the relative growth

[15] op cit 1

factors are likely to be materially different among the species as this can change the net benefit relativities among the species over time.

The three sought after species in this case study are part of wide range of fish species that consumers may buy to eat from retail outlets or at restaurants (and the like) and consumers can substitute among these preferred and other competitive fish species (from other local fisheries or imported) as relative prices change. For instance, barramundi or king snapper taken from the fishery in the State's North West or Atlantic salmon imported from Tasmania or New Zealand.

If such highly competitive markets exist where there are potentially many suppliers, as is the case for the three sought after species from the West Coast 'Wetline' fishery, then it may be reasonable to assume competitive prices and margins would most likely prevail in the longer term. In that case, the likelihood is that, for the case study species, the key factors that drive Xcom for each of these species are likely to be broadly similar and we have therefore considered the key factors that will impact the Xcom growth factors for these three sought after species in this generic way in the following sections. This is unlikely to be the case in the recreational sector, where, as discussed in Chapter 4, product differentiation among the case study species can be important.

## 3.3 Local Demand Drivers

Local market demand for the three sought after species taken from the West Coast fishery will be driven largely by population growth, rising real per capita incomes, and shifting product preferences. These key drivers of local demand for these three species are shown in Table 1 below.

**Table 1: Key Drivers of Local Demand for the Three Key Species Taken from the West Coast 'Wetline' Fishery**

| Key Local Demand Drivers | Annual Rate of Growth (%) |
|---|---|
| Population Growth | 1.40 |
| Real Per Capita Income Growth | 0.70[1] |
| Total | 2.10 |

Notes: [1]Real per capita income growth multiplied by an estimated income elasticity of demand of 0.30

Source: Australian Bureau of Statistics

This suggests local demand for the three locally caught species from the West Coast fishery could be expected grow, on average, by around 2.1% annually all other things remaining unchanged. It assumes that there are no underlying shifts in tastes and preferences of local consumers nor any increased availability of fish species from elsewhere that are competitive substitutes for the three case study species in local consumers' buying behaviour (e.g. barramundi, salmon) or changes in the underlying trends in the cross elasticity of substitution for other meats.

## 3.3 Drivers of Export Demand

The demand for the three case study species in the Melbourne and Sydney fish markets will also be driven largely by population growth, changes in real per capita incomes, shifting product preferences and changing social demographics and competitive supplies available from elsewhere. These key export demand drivers are shown in Table 2 below.

**Table 2: Key Drivers of Export Demand for the Three Key Species Taken from the West Coast 'Wetline' Fishery**

| Export Markets | Population Growth (%) | Real Per Capita Income Growth[1] (%) | Aggregate Driver (%) |
|---|---|---|---|
| Melbourne | 1.24 | 0.81 | 2.25 |
| Sydney | 1.00 | 0.75 | 1.75 |
| Total | 1.11 | 0.78 | 1.99 |

[1]The real per capita income growth multiplied by an estimated income elasticity of demand of 0.30
Source: Australian Bureau of Statistics

Assuming that there are no underlying shifts in tastes and preferences of Melbourne and Sydney consumers or changes in the underlying trends in the cross elasticity of substitution for the three case study species in these markets, then the Eastern States demand for the three case study species could be expected to grow, on average, by around 2% annually all other things remaining unchanged.

## 3.4 Competitive Outlook and Risks

### 3.4.1 Alternative Fish Supplies

The three sought after species taken from the West Coast 'Wetline' fishery represent only a small part of a larger volume and range of fish species available in various forms that local consumers can chose among when making a decision to buy fish to eat. This includes commercial catches of the three key species elsewhere as part of the

16,000 tonnes of fish taken from the State's fisheries, and, importantly, increasingly larger volumes of fish imported into Western Australia in various forms.

Imports of competing species are shown in Figure 4. The actual imports by species and type (smoked versus frozen etc) are given in Appendix 1.

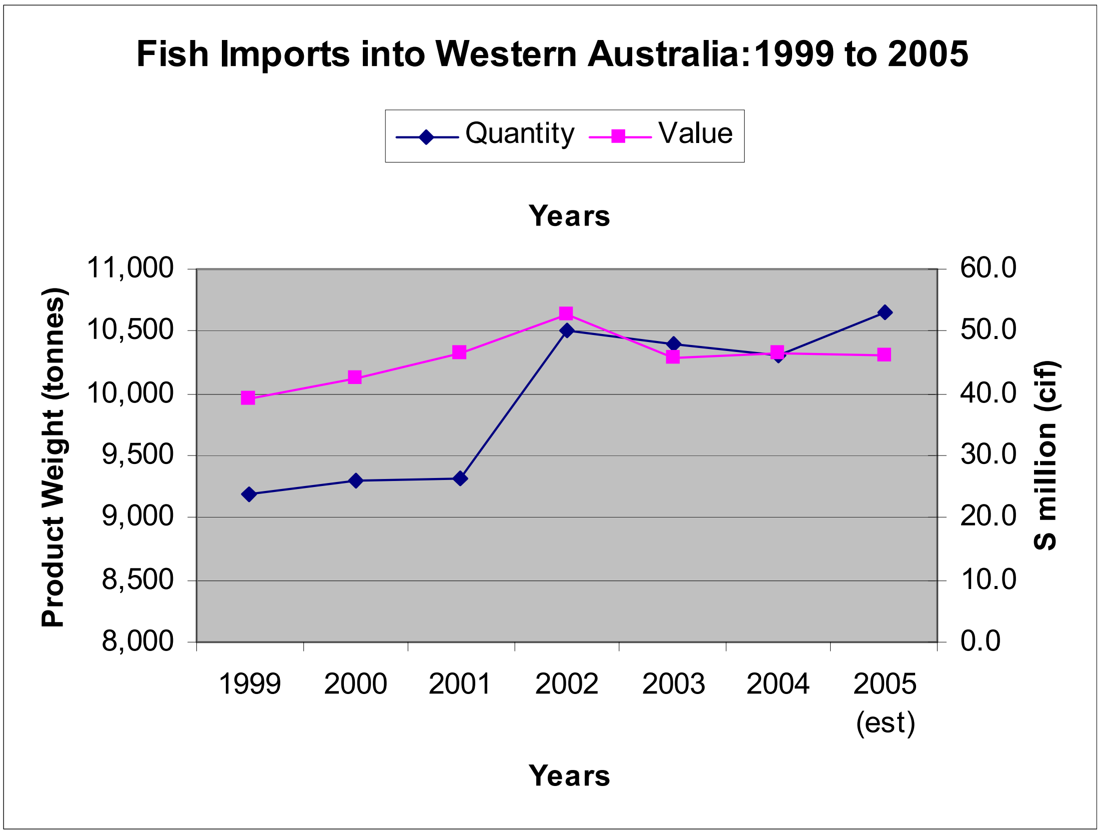


**Figure 4: Fish Imports in Western Australia-1999 to 2005**

Figure 5 below, which shows the total 'fish' supplies and those imported from overseas (see Appendix 1)[16], illustrates this point. (The local commercial catch adjusted for volumes exported overseas is represented by the difference between the imported fish line and the total availability line.) The total fish supplies in Figure 5 needs to be adjusted for inter-State traded fish. The volumes of fish involved in this trade are not available from official statistics.

[16] Based on official overseas trade statistics where product weights were converted into live weight equivalents using conversion factors published by the United Nations Food and Agriculture Organisation

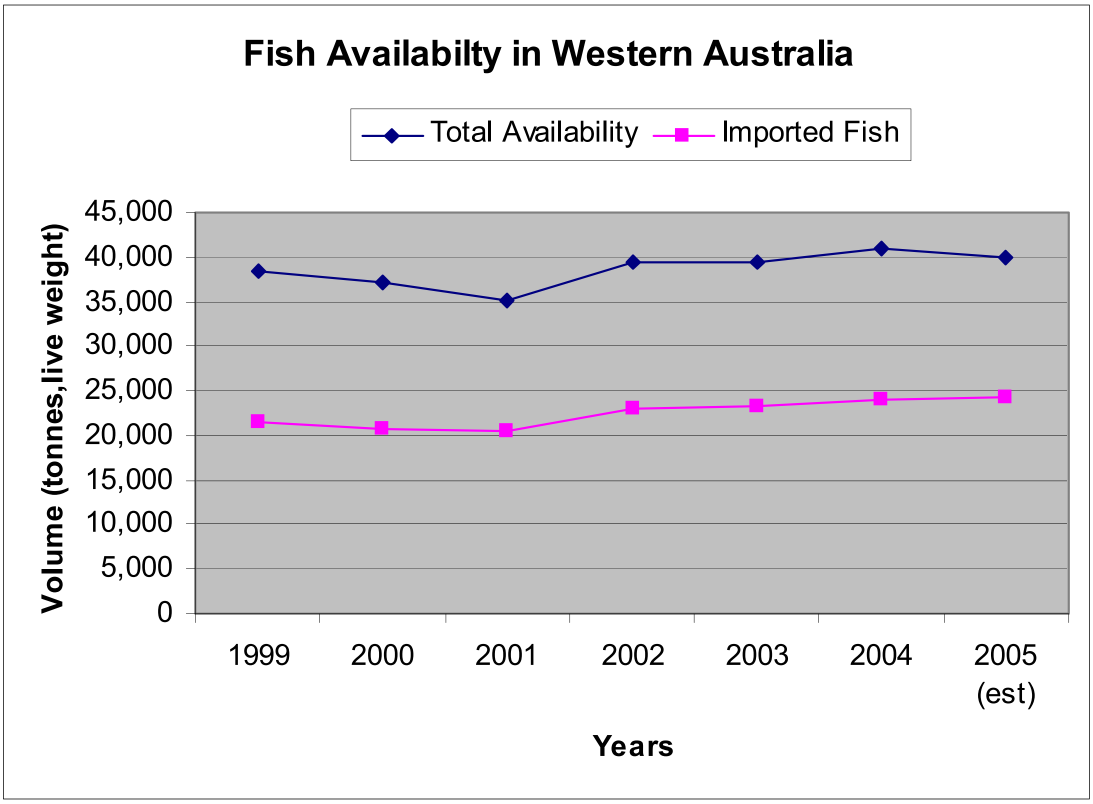


**Figure 5 : Fish Availability in Western Australia-1999 to 2005**

Despite these data limitations Figure 5 provides a useful insight into what is happening to fish supplies locally. Importantly, Figure 5 shows that the increasing volumes of imported fish, which have grown at about 3.0 per cent annually over this period, accounting for the 1.5 per cent increase in the total fish supplies available to consumers in Western Australia given the local commercial fish catch has not increased over this period.

Also, the increasing supply of imported fish can be expected to place downward pressures on domestic prices of local commercial 'fish' catches, including the three key species taken from the West Coast 'Wetline' fishery. This is not an unreasonable assumption to make where there is no evidence to suggest that, in a highly competitive fish market, local consumers will not substitute among fish products as relative price change. In this event, the marginal net benefits from commercial use of the three case study species are likely to be lower than they would be otherwise if the above trend in supplies of imported fish continues.

### 3.4.2 Acquaculture Production of Fish

With wild capture fisheries generally at the maximum sustainable catches, the probability of any substantially increased supply of fish from these sources is likely to be low. If anything, the converse trend is more likely to be true, that wild capture supplies are unlikely to keep pace with demand and that growing domestic demand will be increasingly meet from aquaculture either locally or elsewhere.

There is interest both locally and elsewhere is fish farming. Locally, this includes fish species like barramundi which are among those preferred by Western Australian consumers and which are strong substitutes for the case study species. These developments are in there infancy, but, if proven to be viable operations, this could see increased fish supplies locally that are direct substitutes for the three case study species captured from the West Coast 'Wetline' fishery.

There are other supplies of fish farmed elsewhere which are now well established and increased supplies are appearing on domestic markets as fresh or chilled, whole or filleted, fish. These include species like Tasmanian salmon which are becoming competitively priced locally with the three case study species and potentially competitive substitutes as exposure will ultimately attract increased local consumer interest.

Quantities of other imported farmed fish from, for example, New Zealand, South Africa, Thailand, Myanmar, and Vietnam, have been appearing in local restaurants, and fish retailers. Whilst the later imports are not perfect substitutes for the three case study species, their increased availability can be expected to contain domestic price increases for the three case study species that might not have occurred otherwise.

### 3.4.3 Local Production Costs and Productivity Gains

The changes in input costs of catching and processing fish taken from the West Coast 'Wetline' fishery and productivity gains will impact on producer surpluses or the net benefits attributable to production from commercial use.

Of all the inputs, diesel fuel cost increases have probably been the most notable in recent times. Energy costs at the time of the earlier McLeod and Nicholls study were, on average, around 16 per cent of the total cost of catching and processing fish taken from the 'Wetline' fishery. If the recent diesel price increases (net of rebates) for the catching and processing sector were around 35 per cent, then the overall total costs of catching and processing would have increased by 5.6 per cent as a result of these energy cost changes. This represents a new plateau in energy costs.

To place this in perspective, this would increase the average cost by around 52 cents/kg for the then existing catch volume shown in the earlier McLeod and Nicholls case study and reduce the aggregate average producer surpluses from $3.80/kg to $3.28/kg[17]. Given fuel tend to relatively fixed costs (that is, the level of fuel costs is not determined entirely by the catch volume, particularly in the catching sector where the bulk of the energy costs are incurred), the impact on the marginal costs is likely to be of less significance. Consequently, the impact on the marginal net benefits from commercial use is also likely to be of less significance.

Having adjusted for the recent round of the 'energy price' shocks, the central question is then what is expected to happen to general cost levels in the foreseeable future. If official sources in Australia are expecting general cost increases in the economy to be running at around 2 percent to 3 per cent annually in the foreseeable future, then this could be a reasonable assumption to use for dynamic modelling purposes. This also assumes the opportunity cost of capital are not expected to change significantly from the current level, which is probably a not unreasonable assumption in the current economic policy settings and conditions in Australia.

Productivity gains in the catching and processing sector will help to moderate the impact of these general cost increases. If productivity growth in the catching and processing of these three sought after species from the West Coast 'Wetline' fishery is running at the level prevailing in the fishing industry generally (that is, around 1 per cent annually), then there would be downward pressure on the net benefits attributable to production. If the assumptions about likely general cost increases mentioned above were taken to be reasonable view of the future, then this would mean that the net benefits attributable to production would be declining at a rate of around 1 per cent to 2 per cent annually for the case study species.

## 3.5 The Net Impact of the Interaction between the Key Demand Drivers and Competitive Risks

Catch volumes and fish prices can be expected to fluctuate as they have in the past. The key to the application of the dynamic model is to understand how the underlying trends are likely to play out over time.

If the local wild harvest of fish is at the maximum sustainable volumes but if local fish supplies continue to grow at around 1.5 per cent annually in the foreseeable future due to imports and local demand grows by around 2 per cent annually, then there is likely to upward pressures on local fish prices for the three case study species over time. This could be expected to see fish price rises averaging around slightly more than 0.5 per cent annually (after adjusting for the price elasticity of demand) over time

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[17] op cit 1 Table 1, page 26

where product availability locally expands broadly in line with past trends highlighted above. This does not mean prices will rise by 0.5 per cent every year but they will tend to fluctuate around an underlying price trend with a growth rate equivalent to 0.5 per cent over time.

In the event that cost increases (after allowing for productivity gains) are running against 'wetline' fishing and processing at around 1 to 2 per cent annually, then the marginal net benefits from commercial use of the three key species (that is, Xcom) could be expected to decline by between around -0.5 per cent and -1.5 per cent over time.

# 4 Drivers of the Recreational Marginal Net *Benefit Values – Finding Xrec for* the Three Key Species Taken from the West Coast 'Wetline' Fishery

The application of the allocation model on the recreational side requires that we have an estimate of Xrec in the basic equation:

$$MB_{rec}{}^{t} = MB_{rec}{}^{0}(1 + X_{rec})^{t}\text{, where}$$

- $MBrec^t$ is the recreational marginal net benefit in the future time period t.
- $MBrec^0$ is the recreational marginal net benefits determined from the application of the static model specified in previous research by McLeod and Nicholls[18]. This sets the values for the base period, period 0.
- X*rec* is the percentage annual growth in the benefits; that is the expected annual growth in MB*rec*.

In estimating X*rec* we need to incorporate the various drivers of recreational value as annual percentage growth rates.

Recreational wetline fishing currently has about 45,000 participants. Hence it is a very significant activity and, because of the expense involved, a fishing activity dominated by middle to upper income groups. The survey results in McLeod and Nicholls[19], indicate that 35% of respondents had incomes above \$52,000. They were predominately male (96%) and in the 30-60 age group (75%).

For wetline fishing the key to the estimation of Xrec is to assess how:

- the willingness to pay will increase for the existing participants (the 45,000),
- how the participation rate will increase due to new participants,
- how the participation rate will increase for existing fishers (the 45,000)
- how technology will stimulate demand

We expect that the demand for wetline fishing will increase as a function of:

- annual population growth. In Western Australia this is around 1.7% per annum.

[18] Lindner, McLeod and Nicholls, 2005.

[19]

- annual growth in real income per capita. In Western Australia this is about 2.5% per annum.
- income elasticity of demand for recreational wetline fishing.
- change in the demographic composition of the population over time. For recreational fishing, participation rates and type of fishing, appear to vary with age. This may affect the effort and participation (trips per year) by existing fishers.
- annual percentage change in the underlying real local prices of alternative recreational activities and the cross elasticity of substitution between these alternatives and recreational wetline fishing. If prices of alternative activities fall relative to the "price" of fishing then consumers will shift towards these activities and away from recreational wetline fishing.

For Perth metropolitan area population is around 1.6 million so relative to population the actual participation rate is around 3%.

Keeping the participation rate unchanged means that the cohort of 45000 fishers grows at the population growth rate, somewhere around 1.75 per annum.

How the participation rate will change is of particular interest in the case of the wetline fishery. New participation may grow faster than the population growth rate because of the growth in boat ownership.

At 45,000 participants and with significant entry and on-going costs, largely connected to boat ownership, there are some barriers to increasing the participation rate. However, pleasure boat ownership is growing in Western Australia, as it is elsewhere in Australia and once a vessel is owned, participating in wetline fishing has a much lower incremental cost. Currently pleasure boat registrations in Western Australia are growing at 3% to 4% per annum.

Whilst there is no hard evidence on the way that the participation rate may grow based on vessel ownership, the anecdotal evidence is that it may well be the source of increased participation. Certainly it suggests a participation rate increase. That is whereas maintaining the 3% participation rate suggests growth at the population growth rate, the pattern of growth in boat ownership suggests a rate above population growth with the participation rate growing above 3%.

The overall Perth population is expected to growth at 1.7% per annum. However, it is an aging population with the 55 to 59 age group is expected to grow by 5.9% per annum and 60 to 64 age group expected to grow by 4.9% pa. Wealthy retirees owning boats may be able to increase their effort in terms of trips per annum so that the average of 12-13 trips per annum is increased.

Real per capita incomes in Australia have grown by around 2.5 % per annum over the last decade and this is expected to continue for some years.

There is no data on the income elasticity for recreational wetline fishing. A value of 1.5 has been assumed, reflecting more the view that wetline fishing is a high level recreational fishing activity with a 'sports" orientation and a "luxury" good aspect..

Using these variables we can consider how the demand for recreational wetline fishing activity might rise.

Most conservatively we could set X*rec* based on the combination of the population growth and per capita real income growth (with an income elasticity of 1.5). This gives an X*rec* overall of 5.45% per annum.

However, if the participation rate increased by 1% per annum, than the overall demand growth would be 6.45%.The participation could grow even more, reflecting the growth in boat ownership in which case something above 7% could be indicated.

This is growth in demand to catch additional kilograms of the three prized species against the current recreational catch of 350,000 kilograms.

# 5 Making the Model Operational

The key parameters described in previous sections can be used to calibrate the allocation model. This is done using the wetline specific version of the illustrative model described in Lindner, McLeod and Nicholls[20].

Taking the model and the specific wetline fishery functions as set out above produces a spreadsheet model solution as shown in below.

The growth rates, Xrec and Xcom come from the work in Chapters 3 and 4.

The marginal net benefit from commercial wetline fishing is based on the original study which estimated it to be $6.35 per kilogram. The marginal net benefit for recreational catch is estimated to be $3.83 per kilogram.

The value for the recreational sector was derived from the original contingent valuation study. The inverse specification from that study for willingness to pay function was used to derive a marginal willingness to pay function and to determine the way that the marginal willingness to pay changes as fish/kgs are allocated toward the recreational sector.

The basic recreational choice equation takes the form of a logistic regression with a form:

$$Log[\frac{\Pr ob(yes)}{1-\Pr ob(yes)}] = \alpha_0 + \beta_1 FEE + \beta_2 QTY^{-1} + \sum \beta_i SOCIO = \Delta V$$

where FEE is the specified fee, QTY is the specified quantity, and SOCIO is set of socio demographic and attitudinal variables. For the wetline fishery a range of socio economic variables were significant and the inverse functional form for quantity appeared to work best where in the previous analysis $\beta_1$=-024 and $\beta_2$=-2.036

The marginal willingness to pay or part worth is defined in terms of the trade off between quantity and price which is of the form:

Marginal willingness to pay = $-(\partial(\Delta V)/\partial QTY)/(\partial \Delta V/\partial Fee)$,

For the inverse case this is: $-(-\beta_2 QTY^{-2}/\beta_1)$

In order to solve for the optimal allocation we have to allow for the fact that as stock is adjusted between sectors the relative marginal valuations change. As stock is

[20] Lindner, McLeod and Nicholls, 2005.

allocated to the recreational sector we would expect the marginal valuation of further allocations to decline, all other things equal.

Figure 6, Figure 7and Figure 8 show the allocation results when the *Xrec* is 5% per annum and *Xcom* is 0%, a 5% spread.

The analysis of commercial drivers indicates that this is a generous *Xcom* figure and various factors such as imports growth suggest an even greater downward pressure on commercial values. A figure of -1% is plausible or even -1.5% per annum. Similarly, the balance of probabilities suggests that the recreational growth may be higher than the 5% used. Wetline fishing appears to be a higher income activity where a boat capable of reaching the offshore reefs is needed to pursue the best fishing is needed. As the current group of 45 year olds ages and retires they will have additional time to fish and may increase their activity above the current 12-13 trips per year. A figure of 6% or even 7% per annum is possible.

Figure 9, Figure 10 and Figure 11 show the allocation outcome when *Xrec* of 6% per annum and *Xcom* of -1% per annum are used. Figure 12, Figure 13, Figure 14 and Figure 15 show the case when the *Xrec* is 7.5% per annum and the *Xcom* is -1.5% per annum. Figure 13 shows the allocation share over time and Figure 14 shows the quantity adjustment each year along the optimal path. These various simulation results allow us to consider how the time path of allocation changes as the spread grow a more conservative to more realistic levels

| | Assumptions | | |
|---|---|---|---|
| Annual Growth Rate in Recreational Net Benefits | *Xrec* | | 0.05 |
| Annual Growth Rate in Commercial Net Benefits | *Xcom* | | 0.00 |
| Marginal Net Benefit Recreational Catch Base Year | MB *rec,0* | $ | 3.83 |
| Marginal Net Benefit Commercial Catch Base Year | MB *com,0* | $ | 6.35 |
| Fish Stock to Be Allocated | Q | | 854000 kgs fish |
| Intial Recreational Allocation | Q *rec,* 0 | | 350000 kgs fish |
| Initial Commercial Allocation | Q *com,0* | | 504000 kgs fish |
| Marginal Benefit Functions From Base Year Estimation | | | |
| Recreational MB fucntion constant | $\alpha_{rec}$ | | -2.036 |
| Commercial MB function constant | $\alpha_{com}$ | | -1.478E-05 |
| Recreational MB fucntion slope | $\beta_{rec}$ | | -0.024 |
| Commercial MB function slope | $\beta_{com}$ | | 0 |

**Figure 6: Data Sheet For West Coast Wetline Time Path Model Scenario 1**

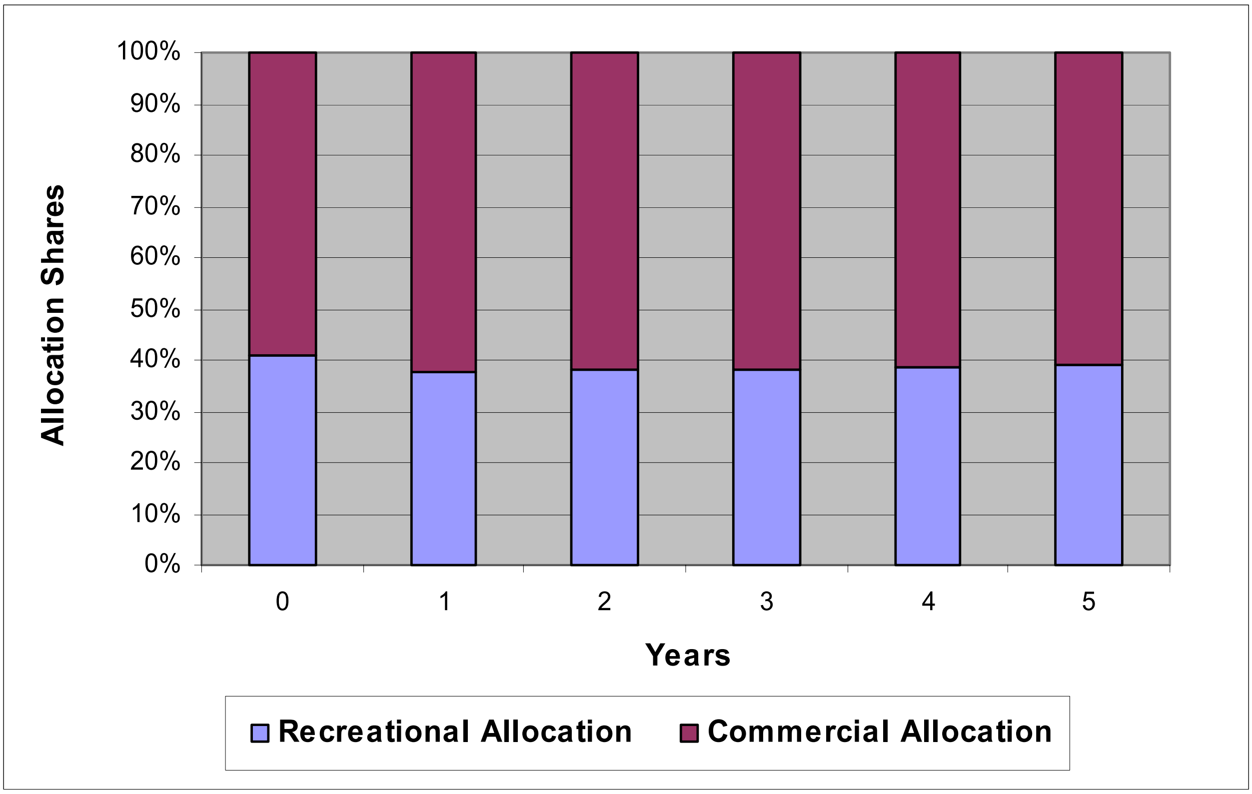


**Figure 7: Time Path of West Coast Wetline Allocation for Data Sheet Assumptions Scenario 1**

| Year | 0 | Year 1 | | Year 2 | | Year 3 | | Year 4 | | Year 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj |
| Q | 854000 | 854000 | 854000 | 854000 | 854000 | 854000 | 854000 | 854000 | 854000 | 854000 | 854000 |
| Q rec | 350000 | 350000 | 321002 | 321002 | 323737 | 323737 | 326551 | 326551 | 329449 | 329449 | 332434 |
| Q com | 504000 | 504000 | 532998 | 532998 | 530263 | 530263 | 527449 | 527449 | 524551 | 524551 | 521566 |
| MB rec,t | 3.83 | 3.83 | 5.9213 | 6.22 | 5.9618 | 6.26 | 6.0034 | 6.30 | 6.0462 | 6.35 | 6.0903 |
| MB com,t | 6.35 | 6.35 | 5.9213 | 5.92 | 5.9618 | 5.96 | 6.0034 | 6.00 | 6.0462 | 6.05 | 6.0903 |
| MB Diff | -2.52 | -2.52 | 0.00 | 0.30 | 0.00 | 0.30 | 0.00 | 0.30 | 0.00 | 0.30 | 0.00 |
| change in recreational allocation required to optimize allocation, year t | | | -28998 | | 2735 | | 2814 | | 2898 | | 2986 |
| change in commercial allocation required to optimize allocation, year t | | | 28998 | | -2735 | | -2814 | | -2898 | | -2986 |

**Figure 8: Worksheet for Optimal Time Path of Allocation Showing Annual Adjustments in Allocation of West Coast Wetline. Scenario 1**

| Assumptions | | | | |
|---|---|---|---|---|
| Annual Growth Rate in Recreational Net Benefits | *Xrec* | | 0.06 | |
| Annual Growth Rate in Commercial Net Benefits | *Xcom* | | -0.01 | |
| Marginal Net Benefit Recreational Catch Base Year | MB *rec,0* | $ | 3.83 | |
| Marginal Net Benefit Commercial Catch Base Year | MB *com,0* | $ | 6.35 | |
| Fish Stock to Be Allocated | Q | | 854000 | kgs fish |
| Intial Recreational Allocation | Q *rec*, 0 | | 350000 | kgs fish |
| Initial Commercial Allocation | Q *com,0* | | 504000 | kgs fish |
| Marginal Benefit Functions From Base Year Estimation | | | | |
| Recreational MB fucntion constant | $\alpha_{rec}$ | | -2.036 | |
| Commercial MB function constant | $\alpha_{com}$ | | -1.478E-05 | |
| Recreational MB fucntion slope | $\beta_{rec}$ | | -0.024 | |
| Commercial MB function slope | $\beta_{com}$ | | 0 | |

**Figure 9: Data Sheet For West Coast Wetline Time Path Model. Scenario 2.**

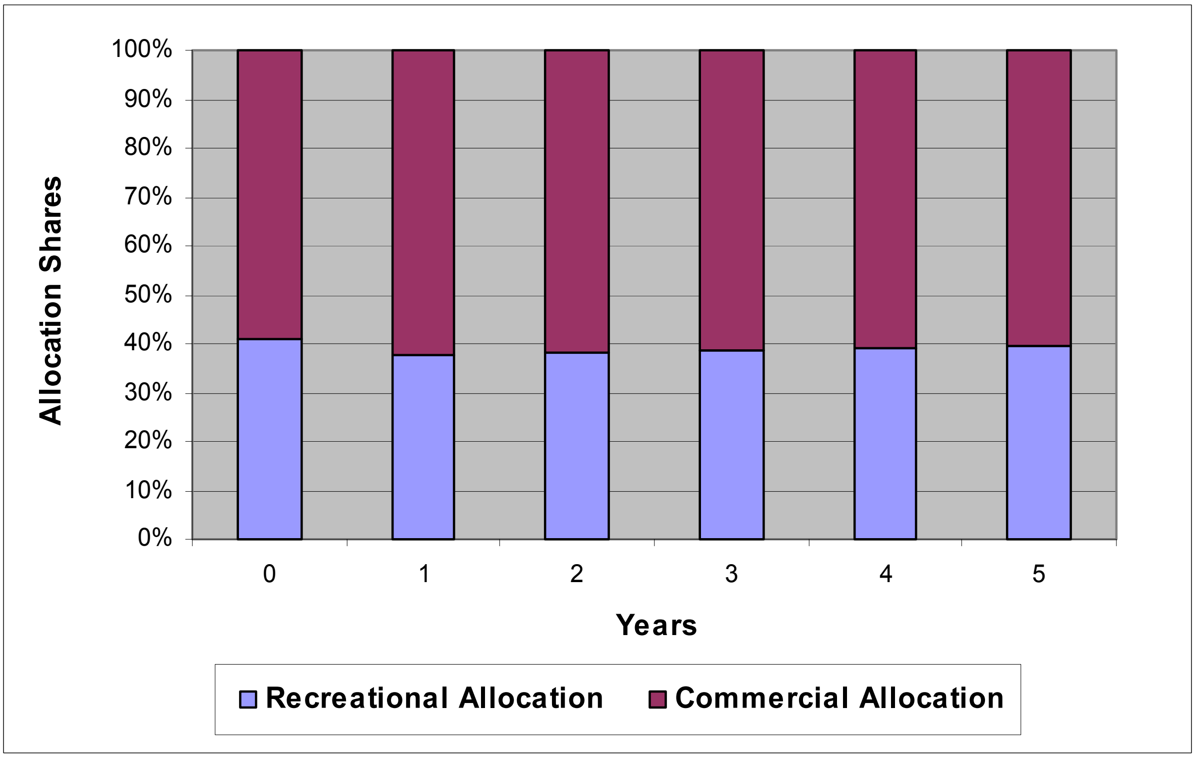


**Figure 10: Time Path of West Coast Wetline Stock Allocation for Data Sheet Assumptions. Scenario 2.**

| Year | 0 | Year 1 | | Year 2 | | Year 3 | | Year 4 | | Year 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Before Allocation Adj** | **After Allocation Adj** | **Before Allocation Adj** | **After Allocation Adj** | **Before Allocation Adj** | **After Allocation Adj** | **Before Allocation Adj** | **After Allocation Adj** | **Before Allocation Adj** | **After Allocation Adj** |
| Q | 854000 | 854000 | 854000 | 854000 | 854000 | 854000 | 854000 | 854000 | 854000 | 854000 | 854000 |
| Q rec | 350000 | 350000 | 321002 | 321002 | 324831 | 324831 | 328776 | 328776 | 332846 | 332846 | 337046 |
| Q com | 504000 | 504000 | 532998 | 532998 | 529169 | 529169 | 525224 | 525224 | 521154 | 521154 | 516954 |
| MB rec,t | 3.83 | 3.83 | 5.9213 | 6.28 | 5.9187 | 6.27 | 5.9179 | 6.27 | 5.9188 | 6.27 | 5.9218 |
| MB com,t | 6.35 | 6.35 | 5.9213 | 5.86 | 5.9187 | 5.86 | 5.9179 | 5.86 | 5.9188 | 5.86 | 5.9218 |
| MB Diff | -2.52 | -2.52 | 0.00 | 0.41 | 0.00 | 0.41 | 0.00 | 0.41 | 0.00 | 0.41 | 0.00 |
| change in recreational allocation required to optimize allocation, year t | | | -28998 | | 3828 | | 3946 | | 4070 | | 4200 |
| change in commercial allocation required to optimize allocation, year t | | | 28998 | | -3828 | | -3946 | | -4070 | | -4200 |

**Figure 11: Worksheet for Optimal Time Path of Allocation Showing Annual Adjustments in Allocation of West Coast Wetline. Scenario 2.**

| Assumptions | | | | |
|---|---|---|---|---|
| Annual Growth Rate in Recreational Net Benefits | Xrec | | 0.075 | |
| Annual Growth Rate in Commercial Net Benefits | Xcom | | -0.015 | |
| Marginal Net Benefit Recreational Catch Base Year | MB *rec,0* | $ | 3.83 | |
| Marginal Net Benefit Commercial Catch Base Year | MB *com,0* | $ | 6.35 | |
| Fish Stock to Be Allocated | Q | | 854000 | kgs fish |
| Intial Recreational Allocation | Q *rec*, 0 | | 350000 | kgs fish |
| Initial Commercial Allocation | Q *com,0* | | 504000 | kgs fish |
| Marginal Benefit Functions From Base Year Estimation | | | | |
| Recreational MB fucntion constant | $\alpha_{rec}$ | | -2.036 | |
| Commercial MB function constant | $\alpha_{com}$ | | -1.478E-05 | |
| Recreational MB fucntion slope | $\beta_{rec}$ | | -0.024 | |
| Commercial MB function slope | $\beta_{com}$ | | 0 | |

**Figure 12: Data Sheet For West Coast Wetline Time Path Model. Scenario 3**

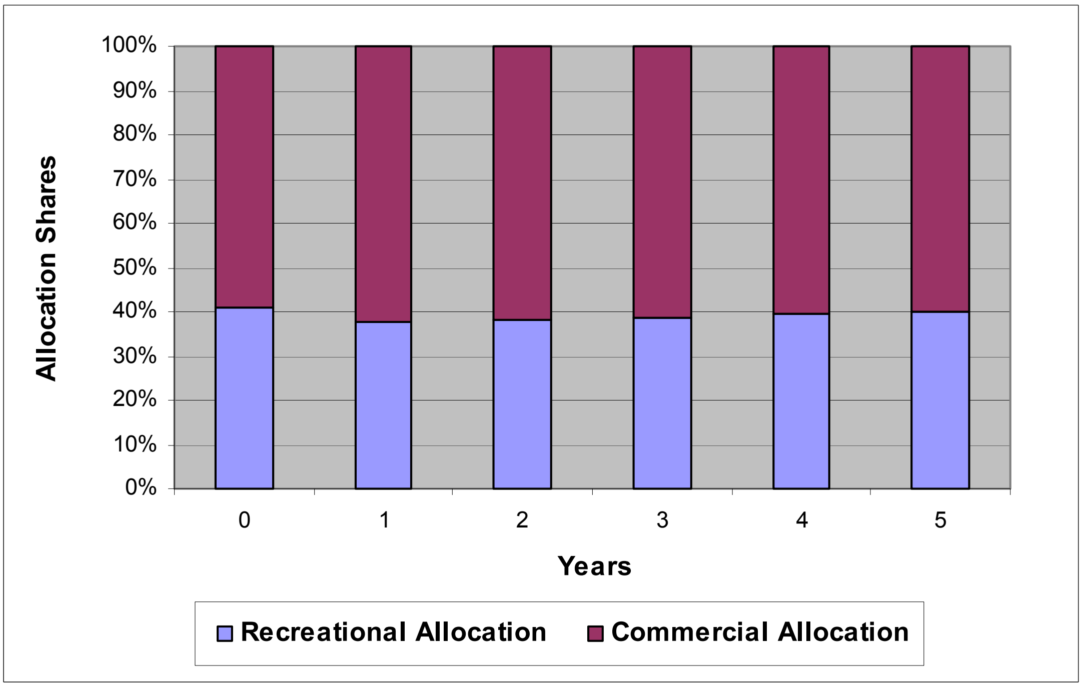


**Figure 13: Time Path of West Coast Wetline Stock Allocation for Data Sheet Assumptions. Scenario 3**

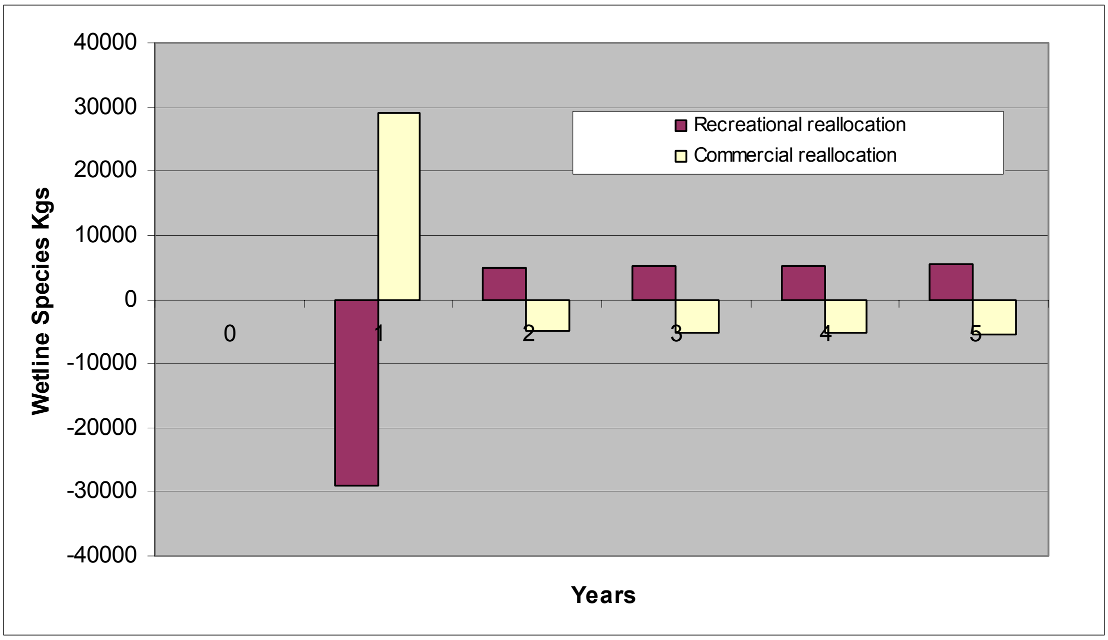


**Figure 14: Quantity Adjustment Along Time Path of West Coast Wetline Stock Allocation for Data Sheet Assumptions. Scenario 3**

| Year | 0 | Year 1 | | Year 2 | | Year 3 | | Year 4 | | Year 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj | Before Allocation Adj | After Allocation Adj |
| Q | 854000 | 854000 | 854000 | 854000 | 854000 | 854000 | 854000 | 854000 | 854000 | 854000 | 854000 |
| Q rec | 350000 | 350000 | 321002 | 321002 | 325924 | 325924 | 331030 | 331030 | 336332 | 336332 | 341834 |
| Q com | 504000 | 504000 | 532998 | 532998 | 528076 | 528076 | 522970 | 522970 | 517668 | 517668 | 512166 |
| | | | | | | | | | | | |
| MB rec,t | 3.83 | 3.83 | 5.9213 | 6.37 | 5.9053 | 6.35 | 5.8922 | 6.33 | 5.8822 | 6.32 | 5.8761 |
| MB com,t | 6.35 | 6.35 | 5.9213 | 5.83 | 5.9053 | 5.82 | 5.8922 | 5.80 | 5.8822 | 5.79 | 5.8753 |
| | | | | | | | | | | | |
| MB Diff | -2.52 | -2.52 | 0.00 | 0.53 | 0.00 | 0.53 | 0.00 | 0.53 | 0.00 | 0.53 | 0.00 |
| change in recreational allocation required to optimize allocation, year t | | | -28998 | | 4922 | | 5106 | | 5302 | | 5503 |
| change in commercial allocation required to optimize allocation, year t | | | 28998 | | -4922 | | -5106 | | -5302 | | -5503 |

**Figure 15: Worksheet for Optimal Time Path of Allocation Showing Annual Adjustments in Allocation of West Coast Wetline. Scenario 3.**

# 6 Policy Implications

The results from the application of the dynamic model to the West Coast 'Wetline' Fishery shown in Chapter 5 give decision makers and stakeholders an insight into the optimal allocation path over time. The model outcomes highlight the direction, extent and timing of stock re-allocations required in the future between the commercial and recreational sectors if socially optimal allocations are to be achieved and maintained under a range of estimated growth factors for commercial (*Xcom*) and recreational (*Xrec*) fishing.

Assuming the total sustainable take of the three key species is in aggregate 854 tonnes and if the estimated range of *Xcom* and *Xre*c values are considered to be reasonable, then this poses an interesting stock allocation challenge for fisheries managers. Whilst the static results (see Figure 1, Chapter 2) from the earlier McLeod and Nicholls report[21] suggest a stock re-allocation of up to 40 tonnes towards the commercial sector and away from recreational use at the present time, the dynamic modeling results suggest that any such re-allocation would need to be progressively reversed over the following four years and beyond years. This is the case under all three scenarios because *Xrec* exceeds *Xcom*. The difference is that, under the most conservative scenario 1 with *Xcom* value 0% per annum and *Xrec* value 5% per annum, the extent of the reversal is less or, if you like, the period of time to complete reversal of the initial re-allocation is longer than under the scenario 3 where *Xcom* is set at-1.5% per annum and *Xrec* is set at 7% per annum..

These results show the importance of looking ahead when making allocation decisions and understanding the drivers of demand and marginal values. A key driver of *Xrec* is recreational participation rates and the conservative estimates assume participation rates are unchanged. Yet, as noted previously, pleasure craft registrations in Western Australia continue to grow significantly at around 3% to 4% per annum. If these rates continue, then this will likely push the *Xre*c rate up over 5%.

Other drivers also are indicative of higher growth in demand to access the wetline resource for recreation. These include:

- the increasing proportion of the existing boat owners entering retirement and the opportunity to increase fishing effort (by fishing more than the current average

[21] Op cit 1

12 -13 trips annually and by adopting improved technology to increase their chances of securing bag limit catches of the three sought after species); and

- the increasing number of new boat owners, which is growing at 3% to 4% annually, who may entering the 'wetline' fishery.

If the higher *Xrec* modeled above arises, so that the recreational marginal net benefits grow at around 7.5% annually (that is, *Xrec* =0.075) and commercial benefits were declining at around 1.5% per annum (*Xcom*= 00.015), then the dynamic model outcomes for the three key species taken from the West Coast 'Wetline' fishery suggest a stock re-allocation of between 4,900 and 5,500 tonnes annually towards the recreational sector. Any initial 40 tonne re-allocation towards the commercial sector suggested by the comparative static model results in earlier research by McLeod and Nicholls[22] would be completely reversed in 5-7 years.

The dynamic modeling outcomes place the static results in perspective and allow structured thinking about the best course of adjustment over time. This then should influence decisions at the current time regarding optimal re-allocations.

An important consideration is whether the future allocation adjustments are uni-directional. In this case they are in that all re-allocation over years following the initial re-allocation is towards the recreational sector. With this knowledge and estimate of the scale of the adjustments needed, the pattern of adjustments can be planned to achieve the best outcomes over a relevant period (e.g. 5 years) making due allowance for adjustment/transaction costs.

The results in Chapter 5 indicate the sensitivity of the allocation path to different assumptions regarding the drivers. The dynamic model can be used for sensitivity analysis. The results above show that if the commercial net benefits were not expected to decline in the foreseeable future (that is *Xcom* = 0) and the recreational benefits were not expected to increase as much because participation rate in the future were not expected to increase as fast (*Xrec* = 0.05), then the outcome would be a slower re-adjustment toward the recreation sector and it would take longer for the indicated initial optimal adjustment toward commercial use to be reversed.

[22] Op cit 1

The results of the application of the dynamic model to the West Coast 'Wetline' fishery assume the total combined 'year-in, year-out' sustainable take is around 854 tonnes for the three key species. As is pointed out in the report, this is uncertain.

In the light of the dynamic modelling results, the scope for any increased commercial fishing activity posed by currently active 'wetline' fishers or by the activation of latent commercial effort as a result of developments elsewhere (for example redirection of effort out of the western rock lobster fishery) could see unplanned stock re-allocations that may not be optimal. Likewise, the unrestricted access to the fishery by recreational fisher could see stock re-allocations exceed those that might be optimal given the likely future growth in recreational participation.

In a policy context, these potentially unplanned effort changes point to a broader sustainability issue to be addressed and resolved first in this fishery, where controls might be designed to maintain existing catch shares given the dynamic modeling results. Once these management changes have become operational and time is allowed for both sectors to adjust and for optimizing behaviour to emerge, the static and dynamic modelling can then be re-calibrated and any future planned adjustments to stock allocations that might be needed to achieve socially optimal outcomes can be determined at that time.

As mentioned above a key driver is the likely future growth in the recreational sector. However, information on likely future recreational fishing behaviour, including likely future participation intentions are currently lacking. Soundly based estimates about the likely behaviour of recreational fishers and of the income elasticity of demand for wetline fishing would help to provide better insights into determining the appropriate growth factors to use for the recreational sector.

# 7 Appendix 1: Fish Imports into Western Australia: 1999 to 2005

| Species | Form | 1999 | | 2000 | | 2001 | | 2002 | | 2003 | | 2004 | | 2005[1] | | Main Sources |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Qty | Value | Qty | Value | Qty | Value | Qty | Value | Qty | Value | Qty | Value | Qty | Value | |
| Salmon | F&C | 1 | 13.8 | 2 | 8.1 | | | | | | | | | | | NZ |
| | Frozen | 1 | 5.6 | 2 | 15.7 | 1 | 6.3 | 19 | 39.3 | .. | 2.7 | 33 | 463.3 | 4 | 55.4 | NZ |
| | Smoked | 40 | 693.5 | 37 | 560.8 | 25 | 535.2 | 28 | 401.2 | 27 | 424.0 | 57 | 903.5 | 30 | 516.6 | Denmark |
| | Canned | .. | 1.7 | 346 | 1183.8 | 454 | 1688.5 | 119 | 644.6 | 188 | 953.1 | 204 | 1019.4 | 300 | 1392.2 | USA, Canada |
| | **Total** | **42** | **714.6** | **387** | **1768.4** | **480** | **2230.0** | **166** | **1085.1** | **215** | **1379.8** | **294** | **2386.2** | **334** | **1964.2** | |
| Tuna | F&C | 1 | 4.3 | 2 | 3.7 | | | | | .. | 0.4 | | | | | |
| | Frozen | | | 8 | 50.8 | | | .. | 0.4 | | | 2 | 28.8 | 3 | 28.4 | |
| | Canned | 1125 | 4491.5 | 1285 | 3730.2 | 1491 | 5206.1 | 1663 | 6476.7 | 1643 | 5501.1 | 1407 | 4697.9 | 1519 | 5393.9 | Thailand |
| | **Total** | **1126** | **4495.8** | **1295** | **3784.7** | **1491** | **5206.1** | **1663** | **6477.1** | **1643** | **5501.5** | **1409** | **4726.7** | **1522** | **5422.3** | |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flat Fish[2] | F&C | | | .. | 2.5 | .. | 0.8 | | | | | | | .. | 3.0 | |
| | Frozen | 66 | 208.5 | 21 | 93.5 | 28 | 153.1 | 15 | 89.1 | 20 | 110.0 | 16 | 97.5 | 29 | 174.8 | NZ |
| | **Total** | **66** | **208.5** | **21** | **96.0** | **28** | **153.9** | **15** | **89.1** | **20** | **110.0** | **16** | **97.5** | **29** | **177.8** | |
| Herring | Frozen | | | 43 | 51.6 | 32 | 28.5 | | | | | | | 1 | 0.7 | UK, NZ |
| | Smoked | 15 | 94.7 | 16 | 126.6 | 7 | 65.6 | 17 | 146.8 | 9 | 74.7 | 7 | 45.4 | 10 | 66.5 | UK |
| | Canned | 100 | 448.3 | 49 | 154.2 | 49 | 85.4 | 26 | 118.7 | 37 | 207.4 | 41 | 171.5 | 54 | 101.3 | Estonia,Denmark |
| | **Total** | **115** | **543.0** | **108** | **332.4** | **88** | **179.5** | **43** | **265.5** | **46** | **282.1** | **48** | **216.9** | **64** | **168.5** | |
| Cod | Frozen | 10 | 42.3 | 39 | 162.0 | | | | | | | | | | | South Africa |
| Sardines | F&C | | | | | 50 | 65.4 | 17 | 27.1 | | | | | 4 | 3.6 | |
| | Frozen | 53 | 62.6 | 18 | 32.0 | 202 | 295.9 | 132 | 215.2 | 130 | 149.6 | 148 | 171.7 | 127 | 132.3 | Indonesia,T'land |
| | Canned | 364 | 1454.4 | 361 | 1353.4 | 227 | 1187.3 | 314 | 1525.8 | 299 | 1226.6 | 202 | 758.7 | 298 | 936.9 | Thailand,Canada |
| | **Total** | **417** | **1517.0** | **379** | **1385.4** | **479** | **1548.6** | **463** | **1768.1** | **429** | **1376.2** | **350** | **930.4** | **429** | **1072.8** | |
| Mackerel | F&C | | | 32 | 29.0 | | | | | | | | | | | |
| | Frozen | 37 | 40.0 | 245 | 224.2 | 17 | 68.8 | 26 | 117.7 | 64 | 69.9 | 4 | 10.1 | 7 | 18.6 | |
| | Canned | 6 | 36.9 | 5 | 32.8 | 5 | 40.9 | 5 | 29.0 | 11 | 74.5 | 9 | 24.7 | 20 | 83.6 | Slovenia |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Total** | **43** | **76.9** | **282** | **286.0** | **22** | **109.7** | **31** | **146.7** | **75** | **144.4** | **13** | **34.8** | **27** | **102.2** | |
| Fish Fillets | F&C | | | 10 | 94.0 | 2 | 7.5 | 9 | 85.4 | 1 | 11.7 | 18 | 190.0 | 8 | 110.5 | Indonesia, NZ |
| | Frozen | 5881 | 25035.6 | 5304 | 27731.4 | 5115 | 29348.9 | 5846 | 33057.1 | 5930 | 28610.1 | 6553 | 30854.7 | 5921 | 27318.8 | NZ, Viet Nam |
| | **Total** | **5881** | **25035.6** | **5314** | **27825.4** | **5117** | **29356.4** | **5855** | **33142.5** | **5931** | **28621.8** | **6571** | **31044.7** | **5929** | **27429.3** | |

**Fish Imports into Western Australia: 1999 to 2005**

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Other Fish | F&C | 6 | 31.3 | 2 | 19.0 | - | - | 1 | 7.1 | .. | 1.3 | 2 | 12.1 | 4 | 33.3 | |
| | Frozen | 274 | 797.0 | 214 | 775.0 | 270 | 1,035.7 | 685 | 2114.3 | 374 | 1029.8 | 312 | 870.3 | 239 | 729.1 | NZ, Viet Nam,T'land |
| | Smoked | 226 | 1286.2 | 207 | 885.8 | 136 | 642.7 | 215 | 1198.9 | 130 | 727.0 | 91 | 459.9 | 95 | 503.5 | South Africa |
| | Canned | 985 | 4522.7 | 1062 | 5280.2 | 1211 | 6028.5 | 1312 | 6354.0 | 1539 | 6756.5 | 1192 | 5619.2 | 1087 | 4788.9 | NZ |
| | **Total** | **1491** | **6637.2** | **1485** | **6960.0** | **1617** | **7706.9** | **2213** | **9674.3** | **2043** | **8514.6** | **1597** | **6961.5** | **1425** | **6054.8** | |
| **TOTAL[3]** | | **9191** | **39271.0** | **9307** | **42600.5** | **9322** | **46490.8** | **10499** | **52648.2** | **10403** | **45930.4** | **10299** | **46398.7** | **9760** | **42391.8** | |

**Notes**: Qty is product weight expressed in tonnes

Value is expressed in $A'000 cif

[1] Estimated by ERA from 11 months data.

[2] Includes Halibut, Plaice, and Sole

[3] The discrepancies between these total figures and the sum of the sub-totals are due to rounding.

Source: Australian Bureau of Statistics