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Western Rock Lobster Stock Assessment and Harvest Strategy Workshop

16 – 20 July 2007

Western Australian Fisheries and Marine Research Laboratories

Department of Fisheries

Fish for the future

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Introduction

Background

The stock assessment workshop, held at the Western Australian Fisheries and Marine Research Laboratories in July 2007, was arranged to fulfil two main objectives. Scientists at the Department of Fisheries were developing a model that will be used for providing management advice for the fishery in the future. It was deemed necessary to have the model peer reviewed by specialists in the field. Secondly, a Marine Stewardship Council (MSC) accreditation condition was for the Department's stock assessment methods and advice for 2004 and 2005 to be reviewed. Professor Norm Hall, of Murdoch University, conducted this review. A further MSC condition was for this review to be scrutinised by a recognised expert(s).

The terms of reference for the stock assessment expert panel to consider were therefore:

1. *To review the current western rock lobster stock assessment process and proposed future research.*
2. *To review a model that has recently been developed by the Department of Fisheries (WA) for use in providing management advice for the western rock lobster fishery and propose future directions for that work.*
3. *To review the current western rock lobster harvest strategy and recommend improvements to it.*
4. *To review Professor Hall's report and recommendations on the 2004 and 2005 western rock lobster assessment process.*

The expert panel consisted of:

1. Dr Paul Breen (National Institute of Water and Atmospheric Research (NZ)
2. Dr Malcolm Haddon (Tasmanian Aquaculture and Fisheries Institute)
3. Dr James Ianelli (National Oceanic and Atmospheric Administration (USA)
4. Dr Richard McGarvey (South Australian Research and Development Institute)

The agenda of the meeting is shown in Appendix 1 and issues raised during each session and outcomes have been listed below.

Workshop procedure

The first day of the workshop was structured to provide background information on the biology and stock assessment of Western Rock Lobster, with the second and third days designed to deal with issues associated with the new model and management strategies. The fourth day of the workshop was set aside for individual reports to be written by the panel (Thursday). Most of the workshop was of a highly technical nature and therefore, in addition to the several invited national and international stock assessment experts, formal participation was limited to researchers and managers responsible for management and policy advice for the western rock lobster fishery, plus representatives of key stakeholder groups (Chair of the Rock Lobster Industry Advisory Committee, Western Australian Fishing Industry Council, Executive Director of the Western Rock Lobster Council, Chair of the Western Rock Lobster Council, Executive Director of Recfishwest and Director of the Conservation Council of WA) furthermore, selected fishers from the northern and southern parts of the fishery were invited to assist with practical views (see Appendix 2). A copy of the Draft Stock Assessment Report, which outlines all data sources and analysis used by the Department in the stock assessment of Western Rock Lobster, was provided to all participants prior to the commencement of the workshop.

It was recognised that with limited general stakeholder participation in the four-day technical workshop, stakeholders needed to be informed in a non-technical way through an open presentation on the last day of the workshop (Friday, 20 July 2007). A full list of those who were invited to the technical workshop and stakeholder presentation is outlined in Appendix 2.

Fishery Background Information

Prior to the presentations that directly related to the four terms of reference, information was presented to the reviewers on the key issues of the stakeholder groups, a biological overview of *Panulirus cygnus*, and a historical management overview of fishery.

Information Presented

Recreational stakeholder view of the workshop

Frank Prokop

(Synopsis constructed by Jason How from notes made during presentation)

Issues related to recreational catch were mainly focused on the mechanisms of how an Intergrated Fisheries Management (IFM) allocation by weight would be done using input controls, and that there is a truncated distribution with the number of lobsters that can be taken by recreational fishers. Other issues include estimates of the recreational catch and how they were attained and the flaws with each of the phone diary and mail survey methods. These were raised as issues from the floor and Frank Prokop acknowledged that there are potential issues arising with both surveys biasing the results. The question of how recreational catch and CPUE data was used in stock assessment was also raised. It was explained that the model doesn't incorporate recreational effort, only catch.

Reviewers indicated that while resource sharing was an issue, the recreational catch was a small component of the overall catch and not a significant factor in the sustainability of the stock.

Commercial stakeholder view of the workshop

Steven Gill

(Synopsis constructed by Jason How from notes made during presentation)

It was noted during the presentation that the current fishing efficiency increases estimated by the Department might not account for more recent technology changes such as mobile phones and improved weather and swell forecasts available on line. This was raised again by the panel, which asked if the commercial fishery was concerned that the efficiency increase was being underrepresented, with the efficiency creep being higher than that estimated by the Department giving rise to some uncertainty with regard to predictions of fisheries scientists.

The option of efficiency creep being combated by a quota system was raised by the panel. The management strategy of input rather than output controls was discussed and Steven Gill felt that quota was not seen as the best way to combat efficiency creep. Since the commercial sector was not confident of the proposed economic benefit behind output controls (quota model) they have chosen to stay with input controls. Further effort reductions under an input system are needed to offset efficiency gains and the industry project is working towards this as an outcome.

Another issue related to the commercial fishery was to find a way to capture the extensive knowledge base of commercial fishers and attempt to utilise this information. Economic considerations were also raised and will be discussed further as part of the economic model.

Biological background information

Roy Melville-Smith and Simon de Lestang

Western rock lobsters only occur on the west coast of Western Australia. Spawning occurs in spring and summer. The larval phase is considered to be 9-11 months. Pueruli settle inshore in depths <20 m, where they remain for most of the juvenile phase of their life cycle. Most migrating western rock lobsters move west of where they first settled as pueruli, but small numbers (<5%) move considerable distances (occasionally >100 km) northward. Mature females become setose around June each year and remain setose until the end of the breeding season, when most moult into a non-setose phase and become available to the fishery. Some mature females (~20%) do not moult to the non-setose phase between February and June. Relationships have been established that show that the proportion of mature females that moult to the non-setose condition between February-June is related to water temperature in January and February; more moulting to non-setose condition when the water temperature is warm in those months. Size at first maturity for both males and females decreases northward in what is believed to be a response to temperature – warmer temperatures relating to smaller size at maturity. There has been a significant decrease in size at maturity for the coastal population. At this stage the change in size at maturity appears to be related to either a general warming of the mean temperature off the Western Australian coast over the last fifty years, or a genetic response to selective fishing practice, or a combination of both reasons. The ‘quality’ of larvae in terms of their ability to survive under hardship have been assessed for females of different size and from different regions on the coast and Abrolhos Islands. Large differences were recorded in the quality of larvae produced by females, but these did not appear to be related to the size of female or her locality of capture.

West Coast Rock Lobster Fishery Management

Kevin Donohue

Fishing for western rock lobster occurs off the lower west coast of Western Australia, between Exmouth Gulf and Cape Leeuwin. There has been a long history of managing fishing activities, commencing in 1887 with the introduction of a minimum size. A major change to management of the commercial sector occurred in 1963 when the number of boats and pots was limited. Since then there has been a trend towards greater regulation of commercial fishing activities, with significant changes occurring in 1993/94 and 2005/06. The commercial sector is managed in three zones under an input management system with total fishing effort controlled. The average commercial catch over the last 10 years was about 11,000 tonnes, with a landed value of between $250 and $400 million. About 490 boats operate using around 54,000 pots. Licensing was introduced for the recreational sector in 1986. Regulations used to manage the recreational sector include limitations on the number of pots used (2 per person), and daily bag limits (8 per person). There is no limit on the number of recreational licences issued. The catch taken by the 36,000 licensed recreational fishers in the 2006/07 season was about 300 tonnes. The biological objective for the fishery is to maintain the breeding stock at or above the levels in 1980. Fishery dependent and independent breeding stock indexes are used to assess performance against the objective. A new initiative aimed at allocating catch shares is under way with a proposal to allocate 5 percent of the catch to the recreational sector and 95 percent to the commercial sector.

Term of Reference I:
To review the current western rock lobster stock assessment process and proposed future research.

Information Presented

Data description and time series analysis
Simon de Lestang and Nick Caputi

The western rock lobster fishery covers more than 100 km of coastline and ranges in depth from the shore to depths of 200 m. Annual average commercial landing are ~ 11 000 tonnes, with this fishery being worth about $300 million to the state. The commercial fishery is managed through effort controls including; limited entry (490 licenses), the number of commercial pots (54 000), temporal closures, spatial segregation of the fishing fleet, lobster size limits (minimum and maximum sizes) and protection of mature females. The department monitors the sustainability of this fishery through a number of programs, namely puerulus settlement monitoring, compulsory monthly fisher returns (CAES), compulsory monthly processor returns, voluntary daily log books, commercial monitoring by research staff onboard fishing vessels, independent breeding stock monitoring and recreational mail and phone surveys. The complementary nature of many of these indices allows for the cross checking of trends and adjustment of biases, which greatly improves the confidence placed around the key indices produced by these monitoring programs. Key indices include catch rates (CPUE), breeding stock indices (Fishery Independent and fishery dependent), harvest rate (depletion analysis), residual biomass (depletion analysis) and puerulus settlement rates. Since these data sets are relatively comprehensive future developments will be focused around moving to electronic recording of raw data, and to increase our understanding of factors that have the potential to bias certain indices, i.e. the influence water temperature has on the catchability of lobsters and increases in fishing efficiency.

Using fine scale catch predictions to examine spatial variation in growth and catchability of* Panulirus cygnus *along the west coast of Australia."
Simon de Lestang, Nick Caputi and Roy Melville-Smith

Puerulus settlement has been monitored throughout the western rock lobster fishery for nearly 40 years. These data have been used to predict the commercial catch in three management zones of the western rock lobster fishery during both the migrating whites (November to January) and non-migrating reds (February to June) parts of the fishery. The catch prediction have always proved very accurate, however in recent years there has been a slight decay in their predictive ability. New catch prediction have therefore been developed, in combination with indices of effort and water temperature, to better represent the recruitment – catch relationship in each 1° transect of latitude in the coastal part of this fishery, as well as at the offshore Abrolhos Islands (total of eight transects). In addition to catch predictions, the fine spatial scales of these models allows them to estimate certain life history traits that are known to affect lobster catches between adjacent fishing ports. This catch modelling has showed that the proportions of three and four year old post-settlement lobsters contributing to the catches varied markedly from the southern to northern transects, suggesting that juvenile lobsters grow faster in the warmer northern and offshore waters of this fishery. These proportions provide accurate estimates of juvenile growth rates, which are vital in the construction of location specific growth algorithms required by the age-structured models used in the management of this fishery. Model estimates of the levels of density dependent mortality during the sedentary "reds" period of the fishery (February – June) were greater in the more densely populated centre of the fishery and far lower at the northern and southern limits of this species distribution. Annual increases in fishing efficiency were also found to be lowest at the northern and southern extremes of the fishery and greatest in the centre of the fishery where technology advances and increased fleet mobility have enabled the fleet to increase catches by 1 – 3% each year while keeping effort constant. The catch modelling was also able to quantify the effect water temperature has on lobster catchability. Catchability (q) was found to be most influenced by water temperature changes in the cooler southern transects, while at the Abrolhos Islands changes in water temperature produced almost no discernable change in q.

Is climate change starting to affect the western rock lobster fishery of Western Australia?

Nick Caputi, Roy Melville-Smith, Simon de Lestang, Alan Pearce and Ming Feng

Environmental factors have been shown to have a significant effect on the western rock lobster fishery of Western Australia. The south-flowing Leeuwin Current and the strength of westerly winds in late winter/spring have been shown to significantly affect the level of puerulus (post larval stage) settlement. The strength of the Leeuwin Current is influenced by the ENSO cycle; the increasing frequency of El Nino events will result in more frequent events of a weaker Leeuwin Current flow. A strong Leeuwin Current is associated with warmer temperatures and a strong eddy structure (which may affect the phytoplankton biomass as measured by the chlorophyll levels) off the coast of Western Australia. Climate change may be causing an increasing trend in water temperature, a weakening of the westerly winds in winter/spring, an increase in the frequency of El Nino events, and an increase in the sea level. These factors can affect the level and spatial distribution in puerulus settlement, size at maturity, size of migrating lobsters, growth rates, catchability, numbers of mature females moulting from setose to non-setose condition, timing of moults and hence the timing of the peak catch rates. Some of these changes (such as the increasing frequency of El Nino events) may have negative implications on the western rock lobster fishery but some such as increasing water temperature may have some positive influence. This paper assesses the impact that climate change may be having on the environmental factors that affect the rock lobster fishery such as water temperature, frequency of ENSO events, Leeuwin Current strength, westerly winds and their implications for the stock assessment and management of the western rock lobster fishery.

Depletion-based population estimates for western rock lobster (Panulirus cygnus) fishery in Western Australia

Ian Wright, Nick Caputi and James Penn

A depletion technique was applied to the western rock lobster fishery in Western Australia for the non-migrating part of the season, March to June. The catch for the migrating part of the fishery was used to estimate the annual exploitation for the whole season. To take into account environmental effects (water temperature and swell) on catchability that affect the assumptions of the depletion technique, estimates of the changes in catchability between March and June of each year were obtained. The trends in catchability, residual biomass and exploitation for three zones of the fishery since the 1983/84 season were examined. These show that the exploitation in the north coastal zone decreased from c. 75% in the early 1990s to c. 60% in the mid 1990s as a result of a major change in management in 1993/94 (including 18% nominal effort reduction and increased protection of mature females). However, in the last 10 years exploitation has increased again to c. 75%, mainly owing to increases in catchability (e.g., efficiency increases) as there has been little change in the nominal effort. The results from this study provide some insight into changes in catchability that can be used in other stock assessment techniques such as length-based assessments.

Key Recommendations from Reviewers & Discussion Points

Communication

- Technical report aimed at technical audience should be produced with a secondary less technical report for industry and non technical stakeholder
- Assessment and management could be made more formal and on a three year cycle.
- Peer and industry involvement in the assessment process itself should be encouraged.

Stock Assessment

- The assessment should consider recreational catch explicitly, though as it is below 5% it should be a relatively low priority.

Fishery-Dependent and Fishery-Independent Breeding Stock Indices

- The large variation in the confidence bounds around the Fishery Dependent Breeding Stock Index in Zone C should be investigated (e.g. examine data sources and General Linear Model).
- The Fishery Dependent and Independent Breeding Stock Indices for each location should be based on the same maturity curves for the same location, and these should be based on the best available data, including maturity observations from the observer sampling.
- Examine how model estimates of the breeding stock reflect patterns seen in either of the Fishery Dependent or Independent Breeding Stock Indices to see if this is a more applicable measure on which to base management decisions.

Fishing Efficiency

- Efficiency increases are not based on rigorous recent estimates.
- Some fishers consider the Departments current estimates of efficiency to be too low.

Data Manipulation and Other Analysis

- Adjustments or scaling of data removes observational quality of the data
- All indices should be reported as uncorrected (for efficiency) values, and these values used as inputs to the model, with the model estimating the efficiency changes.
- Annual data should be presented with its variability (raw form), with smoothed data also presented to highlight trends.
- Ambiguity with assigning catch using logbooks data should be resolved.
- Incorporate standardisation factors for swell and temperature etc. across all data sets where possible. Where there is overlap in time and space of some of the catch rate data sets, standardisation should be fitted to all sets simultaneously.
- Puerulus indices should be run with and without additional collectors that have been added to the site over time. If the overall trend in settlement doesn't change then utilising all collections may improve the estimate of variation.

- Yield per recruit analysis to be undertaken for each zone, as well as egg and value per recruit.

Depletion Study

- Depletion study areas for future:
  - precision might be improved
  - sensitivity to error structures should be explored
  - natural mortality should be included
  - the exclusion of some months is arbitrary and this should be made more rigorous
- Depletion results presented as raw values as well as moving averages

Alternate Data Sources

- Protocols for length data should be reviewed and measuring target numbers revisited, to address representative size frequency data
- Several data deficiencies were identified
  - pot selectivity with respect to size of lobster
  - natural mortality rate (extremely hard to measure in the field)
  - handling mortality: the incidental mortality of lobsters returned to the sea, such as undersized and setose (quite difficult to estimate)
  - gear saturation effects
- Grade category data should be looked at fishery wide as the spatial scale of the data is suspect, but the model should fit it.

Current and Future Directions

Communication

The production of the initial draft "Stock Assessment for the West Coast Rock Lobster Fishery" (Caputi et al. 2007) was well received. Alterations to this report are ongoing, and the report will be adjusted to make it more technical in nature. A subsequent non-technical document will be developed after the technical report.

This will provide the basis for a more structured and formalised assessment and management cycle, including peer and industry involvement.

Stock Assessment

Information on the status and catch of the recreational sector has been a priority of the Department of Fisheries with the recent move to integrated fisheries management. This information that is being refined and improved and will be incorporated into the stock assessment of the fishery.

Fishery-Dependent and Fishery-Independent Breeding Stock Indices

The use of the Fishery Dependent Breeding Stock Index as the primary measure in the decision rules was under examination by the Department of Fisheries prior to the meeting. A big component of the draft integrated model is the output of area specific breeding stock indices (as well as for the whole fishery), which will be based on a broad range of data sources, and thus will presumably be more robust than empirical versions. These, once tested may replace the Fishery Dependent Breeding Stock Index in the decision rules.

Fishing Efficiency

Differing efficiency increases resulting from the depletion and catch prediction analyses highlighted the need to review these estimates. The impact of fishing efficiency on fishery management and persistence of this issue through a number of discussions showed the need for this parameter to be further investigated. The Department is currently in the process of reviewing its estimates of efficiency increase. The stock assessment model will also be used as part of this review.

Data Manipulation and Other Analysis

The points made in terms of some of the standardisations or manipulations performed on raw data have been duly noted, and are being investigated as to their applicability to the indices generated. Other data analysis, in terms of yield, value and egg per recruit will be considered upon the completion of the Western Rock Lobster Council's economic model.

Depletion Study

The areas identified for future investigation in the depletion study have been duly noted and will be prioritised to ensure their resolution in a timely manner.

Term of Reference II:
To review a model that has recently been developed by the Department of Fisheries (WA) for use in providing management advice for the western rock lobster fishery and to propose future directions for that work.

Information Presented

Integrated Stock Assessment Model for the western rock lobster Panulirus cygnus
Peter Stephenson and Simon de Lestang

Within the western rock lobster fishery, *Panulirus cygnus* exhibits spatial differences in growth and sexual maturity as well as synchronous moults. There are two main catch pulses in the fishing season, which extends from mid November to the end of June. The first pulse, from November to January, consists of short period of high catches of predominately 5-year-old animals (4 year post settlement) and a small proportion of fast growing 4-year-olds, locally known as the "whites" catch period. At the start of this period there is a synchronous moult to legal size followed closely by a mass migration from inshore to offshore of highly catchable lobsters with pale "white" shells. The next pulse in catch occurs in February to June and is known as the "reds" period, where the catch is comprised mainly of 4-year-old lobsters, which moulted to legal size at the start of this period. Catch in the offshore areas results from migrated 4 and 5 year-old animals and the remnants from the previous year. The seasonal closure of 4.5 months from 1 July to November 14 is designed to protect the lobsters in the peak spawning periods as well as to reduce effort. The age-sex based model is capable of synthesizing spatially variable growth, migration and size at sexual maturity information in half monthly time steps, across sixteen areas, and incorporates offshore migration. The fine spatial and temporal scale enabled the biological and catch information to be represented realistically. In addition, management changes were evaluated in different areas and on small time scales.

Improving economic efficiency through detailed review of input controls in the Western Rock Lobster Fishery
Stephen Gill
(Taken from FRDC application SG010)

The management system of the Western Rock Lobster Fishery is currently under review. The current process is assessing the best management system for the fishery. The outcome of the review will be a decision to remain with the input control system or a shift to a quota system while still maintaining the input controls during a transition period. Regardless of the outcomes of the review, the fishery will maintain the majority of the inputs controls that currently exist in the fishery. This project will refine some of the previous bio economic modeling work to look specifically at the input controls and how the economic performance of the fishery could be improved by making adjustment to or removing some of the input controls. All of the previous research and modelling that has been conducted will be utilised but refined to focus industry attention on what refinements/adjustments can be made under the input control system to improve the economic performance of the fishery. The current review has built up a level of knowledge and momentum with stakeholders and established a consultation process that has been strongly supported. This project will utilize this momentum and high level of understanding established to investigate potential changes to the input controls that will improve the net economic returns to the fishery. The projects objectives are: 1. Develop an interactive bio economic model that industry can use to assess the biological and economic impacts of modifying or removing input controls in the management of the Western Rock Lobster fishery. 2. An informed and well-educated fishery that sets the future management direction for the fishery whether managed under an input control system or quota system. 3. Clear recommendations to government and fisheries managers on changes to input controls to increase economic returns for the fishery.

Key Recommendations from Reviewers & Discussion Points

Model Structure

- Development of a stock assessment and an economic model was endorsed
- The spatial and temporally explicit nature of the model was commended since it allowed the model to examine both broader temporal and spatial components or single areas.
- Model should be an integrated model with parameters such as growth and depletion being estimated by the model.
- Model should be length-based rather than age based.
- Model should be used for management strategy evaluation.

Data incorporated into the model

- As much of the data as possible should be incorporated into the model, with those less robust data sets given a lower weighting
- Fine scale catch prediction should be incorporated into the model
- Revising the survival equation to the standard Baranov.
- Puerulus data should be used in the objective function.
- Incorporate annual catchability (efficiency) variation from the depletion analysis into the model.
- Include changes in size at maturity into the model
- Incorporate the impact of handling on mortality
- Fit selectivity of commercial pots into the model to estimate the mature smaller females which are escaping and not being recorded in the fishery-dependent breeding stock index
- Error in variables might be better evaluated in the integrated model

Consideration on data sources used in model

- Assumption of constant non-setose proportion after the March moult may have strong effects on results and alternatives should be considered.
- Understanding fleet dynamics will be critical when projecting the model into the future to look at management options. Ways to assign effort into the spatially explicit model should be examined.
- Estimate of the parameter, t_o, in the growth equation was based on the size of two year olds from a single sample of 40 individuals from Dongara. This should be improved by collection of a range of inshore sites in October to better characterise initial growth and size variation

- The origin of the assumed growth coefficient of variation of 0.08 should be made clear and more defensible as it appears to be too small with a value of 0.15 being more applicable.

Current and Future Directions

Model Structure

Many of the recommendations as to the model structure were incorporated into model during the workshop with the expertise of the four reviewers being fully utilised. The model is now an integrated length-based model, and is being designed to evaluate potential changes in management.

Data incorporated into the model

Multiple data sources are currently incorporated into the objective function of the model, including combined commercial and recreational catch, puerulus settlement and Fishery Dependent and Independent Breeding Stock Indices. Further data sources will be added into the objective function in the future, including size category data from processors and depletion estimates of residual biomass and catchability.

Consideration on data sources used in model

With the model being as applicable as the quality of the data used, the suggested improvements to the data inputs are being examined by the Department of Fisheries. Programs examining March setose proportions, growth and fleet dynamics are being planned, or existing data sources being interrogated to provide information on these points. The initial size of two year olds is being examined coast-wide using enclosed pots.

Term of Reference III:
To review the current western rock lobster harvest strategy and recommend improvements to it.

Information Presented

An economic analysis of management options in the western rock lobster fishery of Western Australia
Neil Thomson & Nick Caputi

The Western Rock Lobster Fishery, which is located on the lower west coast of Western Australia, is the largest rock lobster fishery in any county. It supports about 550 lobster fishing boats and has an average annual catch of 11,000 tonnes valued at about $AUD250 million. The sustainability of the fishery is maintained by limiting total allowable effort (TAE), managed through an individually transferable effort (ITE) system. Ongoing improvements in the effectiveness of rock lobster fishing, have placed increased pressure on the fishery and an assessment of the estimated 'sustainability index' has indicated that an effort reduction of about 15% is required in one of the three management zones of the fishery, to ensure there is an adequate breeding stock for continued sustainability. Management options (such as reductions in the number of traps allowed to be used in the fishery, seasonal closures and changes to the maximum size of lobsters taken) to achieve the 15% TAE reduction for the zone vary in the way they could impact on the fishers' financial position because they have different impacts on the value of both the income and expenses. The expected annual net revenue (average revenue net of average fixed and variable costs) of fishers, under different management scenarios, is modeled to determine which has the least negative impact (or as occurs in some cases, the most positive impact) on the net revenue of fishers. The results of the study (which assessed both Year 1 and Year 2 impacts) were provided to the rock lobster industry and the Western Australian Government's industry advisory group in order to assist in the decision making process. The assumptions used in the analysis were also provided to fishers so that feedback could be garnered in order to gauge the veracity of the results. The analysis showed that the most efficient management options were those that involved closing the fishery during periods when the catch rate of rock lobsters is low. These periods (ranked from the most efficient to the least efficient in Year 1), included: (a) 21 days from 15 January to 10 February; (b) 16 days from 15 November to 30 November; (c) late season closures for 3 to 7 days around the full moon; (d) June closure; and (e) early season closures for 3 to 7 days around the full moon. By the second year all of these closures resulted in increased net revenue due to the cost savings and the reduced negative impact on catch.

Current and Future Decision Rules for the Management of the Rock Lobster Fishery
Kevin Donohue and Nick Caputi

Since 1993/94 the management of the fishery has been guided by the biological objective of conserving the breeding stock. Specifically, that the management arrangements maintain the abundance of breeding lobsters at or above the levels in 1980. Significant changes to management arrangements in 1993/94 and 2005/06 were driven by the biological objective. A fishery-dependent breeding stock index has been used to measure performance against the biological objective. A fishery-independent breeding stock index, harvest rates and residual legal biomass have also been used as additional information in the assessment of the status of stocks. In 2004 the biological objective was embodied in a decision rules framework. This framework included specifying the difference management responses based on reference points: Threshold and Limit. The threshold being the minimum standard below which management action is required and the limit being the minimum standard below which immediate significant management is required. The decision rule framework underpinned the management changes made in 2005/06. The Department proposes to improve the framework by incorporating harvest rate. Incorporating harvest rate requires resolution of a number of issues including which is the best measure and what are the target (optimum biological or economic level), threshold and limit levels. Further consultation with industry will be required prior to adopting the new framework.

Key Recommendations from Reviewers & Discussion Points

Decision Framework

- The model of decision rules framework presented to the reviewers, which included breeding stock and harvest rate, was endorsed.
- The empirical 1980 level is a good reference point for breeding stock
- Addition of harvest index to the management structure was endorsed
- Uncertainty should be incorporated into the decision rules framework with a more precautionary approach to thresholds “Prob($BSI_{now} >= BSI_{1980}$) > 0.75 and even more cautious approaches for limits (Probability>0.9)
- The model would enable a more robust measure of the variables being examined in the decision rule (e.g. breeding stock and harvest rates).
- Model outputs should be evaluated prior to their adoption in place of current empirical measures

Harvest Rates

- Harvest rates are exceptionally high and are a matter of some concern, though they are only for the exploitable biomass (undersize, setose and oversize females are excluded)
- Catch per unit effort may rise modestly with lower harvest rates

Effort Reductions

- Recent effort reduction has been timely with high exploitation and low settlement years to come
- Pot saturation at the Abrolhos means that small pot reductions will have little impact on catch.
- Economic concerns were raised with regard to the levels of fishing effort
- Efforts to enhance sustainability through effort reductions have also aided in reducing fishing costs

Current and Future Directions

Decision Framework

The uncertainty around the stock assessment estimates (e.g. breeding stock and harvest rate) highlighted by the reviewers was already recognised by the Department of Fisheries, and will be incorporated into the new decision rules as they are developed. The use of an integrated model to provide estimates of parameters used by the decision rules was one of the primary aims of the models development, and the reviewers supported this approach.

Harvest Rates

These were noted previously by the Department of Fisheries as being high, and were one of the catalysts for their inclusion in the new decision rules framework. As such, under the new framework, exploitation (harvest) rates will be controlled through threshold and limit reference points, which will be determined in the near future.

Effort Reductions

As an input controlled fishery, effort reduction is the primary tool in management of the stock. The reviewer's statements reaffirm the Department of Fisheries previous effort reduction package of 2005/06. Previous effort reductions have served to eliminate a lot of the latent effort in the fishery, with future reductions potentially having a greater impact on catch reduction. However, the concern of pot saturation has been already noted by the Department of Fisheries in Zone A. The impact of the current management package on these factors will continue to be monitored in Zone A and the two coastal zones.

Economic Considerations

This was of considerable importance to stakeholder participants in the workshop, and this was duly reflected in the reviewers' comments. Economic modelling is currently being undertaken by a consultant for the Western Rock Lobster Council, with its outputs to be paralleled with the stock assessment model to determine optimum economic outcomes for the fishery. These will aid in the development of target reference points for the decision rules framework.

Term of Reference IV: To review Professor Hall's report and recommendations on the 2004 and 2005 western rock lobster assessment process.

Information Presented

A copy of Norm Hall's report "Review of the 2004 and 2005 stock assessments of the Western Rock Lobster fishery" was provided to the reviewers. During the workshop, Norm Hall presented his findings and progress made by the Department of Fisheries subsequent to the reports submission.

Key Recommendations from Reviewers & Discussion Points

- Norm Hall's report was comprehensive and well informed
- Most of the recommendation of the Hall report have been addressed

Current and Future Directions

The strong endorsement of the Norm Hall report by the independent reviewers affirms the outcomes of his report, with many of the recommendations being reiterated by the reviewers in their reports. Many of the points highlighted by the Hall report have already being incorporated into the Departments stock assessment process or are underway or planned.

Reviewers Reports

Dr. Malcolm Haddon

Western Rock Lobster Assessment Review

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The terms of reference for this review were:

(i) To review the current western rock lobster stock assessment process and proposed future research;

(ii) To review a model that has recently been developed by the Department of Fisheries (WA) for use in providing management advice for the western rock lobster fishery and propose future directions for that work;

(iii) To review the current western rock lobster harvest strategy and recommend improvements to it; and

(iv) To review Professor Hall's report and recommendations on the 2004 and 2005 western rock lobster assessment process.

Apart from the last term of reference there was considerable overlap among these separate points. My comments below relate to different terms of reference in a mixed way combining discussion where the subject matter seemed to flow best.

The Stock Assessment Process

The stock assessment process is currently evolving from what may be characterized as an empirically based set of informal rules and guidelines into a more formal model based assessment centred around defined limit and target reference points concerning the sustainability of the resource and the economic performance of the fishery. This evolution will involve a period of transition where both approaches are used so as to cross check the validity or consistency of the advice provided by the two approaches. To make the transition will require that the current rules and guidelines be more formally defined as limit and target reference points, along with decision rules for management responses to changing assessments of the resource status.

This review will begin with a brief description of the current assessment process followed by a description of the process into which it should evolve and the requirements of that evolution. This will require a description of the terminology of management strategies, reference points, and decision rules, with some suggestions as to the possible structure of such processes for the western rock lobster fishery. It should be noted that the Western rock lobster fishery benefits from large data sets of good quality data collected over a wide area. The current analyses are basic but sufficient to the purpose and the success of the management over the past decades testifies to the quality of the work. The current assessment processes, however, can no longer meet all of the requirements being asked of the assessment so the present developments are necessary.

The Current Stock Assessment Process

The primary purpose of a stock assessment is to characterize the status of a fishery in terms of the objectives that have been adopted for that fishery. It is only by determining whether or not the fishery is achieving its objectives that it becomes possible to decide whether management intervention is required. For example, it has been declared that the western rock lobster fishery has as its principle biological reference point the objective of "maintaining the abundance of breeding lobsters at or above the levels observed in 1980" (Caputi *et al*. 2007). It was decided that this can be determined by estimating the fishery dependent breeding stock index (FDBSI) for the northern and southern zones, which is defined as the standardized eggs per pot lift, measured as a three year moving average, from the deep water spawning grounds during the spawning season (Sept – Feb). The fishery dependent breeding stock index is known as a fishery performance measure. Each year, by making this calculation the stock status can be determined and decisions made as to whether or not management intervention is required. In practice, in a qualitative way, the fishery dependent breeding stock index is used in conjunction with the puerulus settlement and catch prediction studies and analyses to predict whether the breeding stock index is expected to decline or increase over the next few years. If the predicted trajectory would take the FDBSI below the levels observed in 1980 then some form of management intervention would be recommended.

The western rock lobster fishery is managed through the use of input controls (effort limitations rather than catch limitations or output controls). One serious problem with using input controls is the influence of technical improvements to the quality of fishing effort. So-called "effort creep" has the effect that while nominal effort may stay constant the effectiveness of that effort increases. Under circumstances of effort creep if catch rates were reflective of stock size and remained stable this would mean that the stock was, in reality, declining. It is accepted that effort creep has been and is occurring within the western rock lobster fishery, however, this is very difficult to quantify, especially when the changes to efficiency derive from improved communication and information. The best way of representing changes in catching efficiency in a modelling framework is to modify the catchability coefficient. Catchability is defined as the proportion of the available biomass taken by one unit of effort. With this definition effort creep has the effect of increasing the catchability within an assessment.

In recent years stock depletion analyses have been added to the analyses conducted to assess the stock status of the western rock lobster. Assuming their assumptions are met, depletion analyses can provide estimates of harvest rate and of catchability (with respect to exploitable biomass). In this way they are independent of whether catchability is changing through time and hence act as a check on the extent of changes to catching efficiency. The estimates of harvest rate and catchability are used, again qualitatively, in conjunction with the estimates of FDBSI and predicted catch to determine whether the rock lobster stocks are growing or declining with critical values being determined with respect to the levels observed in 1980.

When the performance measure of breeding stock index is estimated to have values that would lead to recommending a reduction in fishing effort there is currently no simple method for determining the size of any reduction in effort that would be effective in returning or maintaining the FDBSI at or above the 1980 level. There is the empirical evidence of previous effort reductions and the impact they exhibited and this may be used a guide. There is an early age-structured model by Hall and Chubb (2001) and this has been used to determine that the 1980s level of the FDBSI was approximately 20% of the unfished levels and has also been used to guide previous effort reductions. However, Hall's (2007) review of the 2004 and 2005 assessment process points out that: "Unfortunately, the current Hall and Chubb (2001) model needs to be improved or replaced as the outputs that it produces are considered to be less reliable that the time series or empirical data that are available." (Hall, 2007, p4). This statement was made mainly because growth was not considered to have been modelled well and the relative weights ascribed to the various time series of data were considered arbitrary.

The development of the new size-based integrated assessment model is an attempt to draw all of these sources of data together and provide a more robust modelling framework within which to estimate the performance measures and make predictions about the implications of alternative management responses.

Harvest Strategies, Performance Measures, and Reference Points

Management advice for the utilization of fisheries resources is best produced from the outcomes of stock assessments that characterize the status of a stock with respect to a set of performance measures. These performance measures should ideally be based around exploitable or spawning stock biomass, or fishing mortality/exploitation rates, but if these are not achievable then some index of relative abundance could be used (perhaps catch rates or the results of a survey). Given a performance measure, for example the Breeding Stock Index, then it should be possible to define a target reference point, which is deemed an acceptable and desirable state for the fishery to achieve. There should also be a limit reference point, beyond which the fishery should not go, and which if reached requires a strict management response, such as a major reduction in effort or even closing the fishery. In addition, ideally, there should be some threshold reference point beyond which catches or effort is restricted to an increasing degree until the Limit Reference point is reached. This threshold may even be coincident with the target reference point. The manner in which the fishery is restricted would be termed a decision rule (Fig. 1).

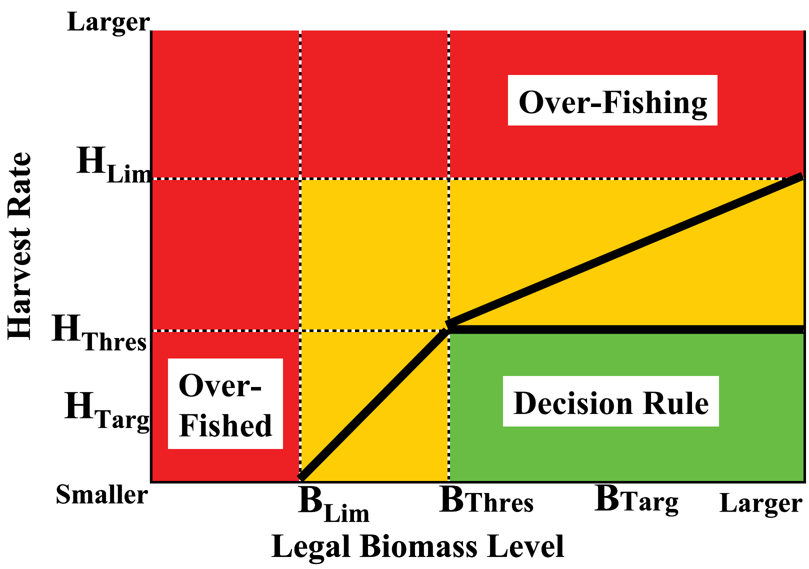

Figure 1. Diagrammatic representation of different reference points for breeding stock index and harvest rate. There are limit, threshold, and target reference points for each performance measure. When harvest rates are unsustainably high, overfishing is said to occur. When the breeding stock index is too low the then stock is said to be overfished. If the performance measures lie within the green zone no action is required. If they lie within the orange zone then intervention is required to lower the harvest rate or rebuild the stock biomass, perhaps following the black line decision rules illustrated. If the performance measures lie in the red regions then stronger management action is required.

An assessment should provide estimates of quantifiable performance measures and the objectives for the fishery should be couched in terms of those performance measures. Typically, reference points would be defined for each performance measure and the estimate compared with the target, the threshold and limit reference points to determine what action, if any is required.

Current Biological Reference Point

The present biological reference point behaves or is used as if it were a Target Reference Point. Management action is only instigated if the Breeding Stock Index threshold is breached, which will tend to keep the BSI in the vicinity of the 1980 threshold. The current instantiation of the reference point does not take uncertainty in the data inputs into account. The median estimate of the performance measure is taken as the value to be compared with the biological reference point. In probabilistic terms it is equivalent to stating that the reference point is achieved if the probability of the current BSI being greater than or equal to the BSI in 1980 is greater than 50%:

$$\text{Prob}(BSI_{Now} >= BSI_{1980}) > 0.5$$

Where BSI is the performance measure (Breeding Stock Index) and BSI_{1980} is the index level observed in the 1980 fishing season. When the MSC assessment and other reviews recommend that the decision rule framework should account for uncertainty it is the use of the median value, the 50% probability, that is being criticized. The standard is that in the face of uncertainty in the data and our understanding of the system being assessed it would be more precautionary if were we 70 or 80% sure that the performance measure were above the target, e.g. :

$$\text{Prob}(BSI_{Now} >= BSI_{1980}) > 0.75$$

Whatever the actual figure (in this case 0.75) it could be agreed upon initially with stakeholders but eventually could be explored in a Management Strategy Evaluation framework.

While having a target reference point which defines a desirable state for the fishery it is also important to define a Limit Reference Point beyond which the fishery should not go. In terms of the BSI, the probability of maintaining the stock above the limit reference point should also be stated explicitly (for example):

$$\text{Prob}(BSI_{Now} >= BSI_{Lim}) > 0.9$$

Ideally the reaction to the performance measure breaching these reference points should be stated explicitly prior to such events. This would entail the formal statement of a decision rule. Thus, for example, the extent to which the performance measure is below the target reference point (or above the limit reference point) could determine the extent of any effort reduction required to return the stock to the desired target or away from the undesirable Limit.

The use of the breeding stock index as the biological reference point acting as a proxy for sustainability appears well founded. However, the current assessment, based as it is on a series of statistical relationships does not pay enough attention to the uncertainty in the data series contributing to the estimates of BSI. An estimate from an Integrated Stock Assessment Model should be able to provide a more robust estimate of the performance measure, which synthesizes many sources of data while accounting for the underlying uncertainties. The current development of such an integrated assessment model is an important improvement to the assessment of the western rock lobster fishery. It should also provide opportunities for the exploration of other performance measures that could be used in addition to the Breeding Stock Index. For example, harvest rates could be combined with the BSI to provide a more inclusive decision rule framework.

Stakeholder Input

The annual lobster tour in which the summary of information and expectations of the resource assessment team for the stock are communicated to the stakeholders along the coast appears to be an effective mechanism for presenting information and hearing the concerns of the Industry. Currently, the biggest disjunction between the Industry and the assessment is that Industry members are aware and worried about the extra distances they are having to travel to catch the lobsters. This is reflected in more catch coming from the deeper waters and reduced catches from the white run in recent years. The present assessment process does not capture the effect of fleet dynamics at all well but the new Integrated Assessment is spatially structured into shallow and deep areas, which should enable such dynamics to be examined. One of the biggest problems for spatially structured stock assessment models is how to implement the fleet dynamics when using the model in projections into the future while exploring the implications of different management options. In other words, how is the distribution of fishing effort to be simulated in risk assessment projections? It is possible to use a simple ratio of spatially distributed effort from the present projected into the future. Alternatively, a statistical analysis relating the model predicted catch rates or harvest rates from different areas and their observed levels of effort can be used to predict the distribution of effort into the future in a dynamic manner. Finally, a detailed model of fleet dynamics could be developed. However, this latter course is complex and is only recommended if the alternatives prove to be incapable of capturing the realities of the fishery. Whichever approach is used will require a detailed examination of the present fleet dynamics before successful risk assessment projections can be made.

Growth

In the Caputi *et al.* (2007) lobster growth is described using an inverse logistic growth function (p 42- 46). Some small points need attention is this section. The equations 3.8.1 and 3.8.2 contain an important typological error, the –Ln(19) in both equations should really be Ln(19), otherwise the growth will not be an inverse logistic.

The initial size of two-year old fish at Dongara was determined from a sample of 40 lobsters taken in October 2004. This sample was used to characterize the mean expected length and the spread (standard deviation) of values around the mean. These estimates (mean length of 39.8mm carapace length with a standard deviation of 6.076) were then adjusted for areas south and north of Dongara, with the mean length being made larger southwards and smaller northwards but the same standard deviation being used in all areas. A minor improvement would be to collect samples of animals in October from each inshore region so as better to characterize the initial growth and variation in size.

The origin of the assumed coefficient of variation of 0.08 for the cumulative growth increments is not clear in the document. From the simulated growth in the new model the use of 0.08 to characterize the total variability appears to be too small, leading to modal groups which are too distinct. The origin of the 0.08 should be made clear and defended more appropriately.

Puerulus Collection

The number of collectors at each site has not always remained constant; as stated: "At some locations additional collectors have been added over the years for various reasons. To maintain the consistency of the indices produced from these sites, additional collectors added over the years are not used in the analysis" (Caputi *et al.*, 2007, p 54). To improve the estimates of mean settlement per sampling period it may prove useful to compute the indices with and without these extra pots. The overall trend in puerulus settlement should not change greatly but the estimate of variation may be improved.

Review of Norm Hall's Review

This review of the work from 2004 and 2005 contains a detailed description of the data series and analyses that have been used to assess the western rock lobster. This is about the current approach and provides many useful insights. It is clear that many of the recommendations of the Hall review are already being implemented, which demonstrates its value. The generation of the technical document itself (Caputi *et al*. 2007) was a recommendation in the Hall report. The advent of the new Integrated Assessment model expands the context into which the Hall report fits but this retains relevance and value as its recommendations are worked upon.

Summary

1. The assessment process for the western rock lobster is evolving. The present assessment met the practical needs of the fishery to date but the advent of MSC certification and improved management regimes required the development of a more general assessment that could answer broader questions about management options. The processes being put into place should meet the needs of the fishery well into the future. There is an on-going need to maintain the collection of quality data from the fishery, perhaps with improvements in the amount of information on the spatial distribution of effort and catch.
2. A new Integrate stock assessment model has been developed by WA Fisheries. This appears to be capable of generating estimates of performance measures based on a synthesis of all data streams. In addition, the model should enable many more management options to be explored in a quantitative manner. The ability to estimate the degree of increase or decrease of fishing effort required to maintain sustainability will be an advantage to the management of the fishery.
3. The current harvest strategy revolves around an estimate of the Fishery Dependent Breeding Stock Index, which acts as a proxy for stock size and sustainability. The generation of the new Integrated Model will allow this performance indicator to be estimated from a broad range of available data. It will enable the harvest strategy to be formalized and expanded to include reference to the harvest rate as well as the stock size. Managing on both these factors will be safer for the stock than managing on only one.
4. Professor Norm Hall's review of the 2004 and 2005 assessment process provided a detailed and well written summary and overview of the fishery, its management, its strengths and weaknesses. Many of his recommendations have already been initiated or put into place. His review was thorough and useful, pointing the way to many sensible and needed developments.

Dr Rick McGarvey

Review of Workshop Terms of Reference for the WA Rock Lobster Stock Assessment and Management Workshop

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24 July 2007

In this review, I will address each of the terms of reference (TOR) in turn. Rather than try and cover all aspects of each, I will attempt to focus my comments on specific aspects that might be important or of particular interest.

TOR 1: To review the current western rock lobster stock assessment process and proposed future research

While perhaps less regular than some, with major management packages implemented about once per decade, I see no major problems with the overall process. The stock assessment is supported by an extensive and informative data set. However, I will suggest possible avenues for improvement.

Stock assessment reporting

I am not sure why there was not a full stock assessment report produced at regular intervals, but some comments suggested it was due to the difficulty of producing a document readable by both managers and scientists, and by industry. However, the current 2007 document that we reviewed fills that need.

In South Australia we also use the 'living document' notion. This was also the approach advocated by Professor Hall in his MSC review. This removes the expectation that the document will be completely new each year. Bits that require it are updated, while still presenting a stock assessment report that is sufficiently complete each year. In SA, yearly stock assessment reports are internally reviewed by two SARDI scientists.

Norm Hall and other panel members offered recommendations for improving the report's structure and contents. I found it well written, and clear.

The consultation with industry (and managers) in the stock assessment process is on-going and extensive and I was impressed with the clear involvement and reasoning of industry in this process.

Fishery-dependent breeding stock index (DBSI).

The principal time series index (indicator) for stock management and decision rule is the fishery-dependent breeding stock index (DBSI). There are a number of inconsistencies in this index that are worth noting.

This index, in the Zone C only Fig. 4.6b, p. 63, Stock Assessment report) has very wide confidence intervals and very substantial year-to-year variation that is not evident in the northern Zone B index. This yearly variation is such that even quite wide CI's in some neighbouring years do not overlap.

While very high exploitation rates could induce spawning stock to rise and fall yearly with variations in puerulus settlement, we know that, in Southern Zone C, fishery catches and puerulus settlement do not. Rather, the impressively close agreement of puerulus index and yearly catches (Fig. 5.2, p. 101) imply that, in this zone, both puerulus settlement and catch vary smoothly over an approximate 4-year time scale.

Because catch depends primarily on newly recruited lobsters following each moult, while the spawning stock includes additional longer-lived protected females, setose and over-size, the spawning stock comprises a number of successive year classes, and therefore should presumably vary less, rather than much more, on a yearly basis than indices of puerulus and catch.

Moreover, the DBSI in Zone C differs from the fishery-independent index (FIBSI) in several important ways:

1. The FIBSI does not vary greatly from year to year.
2. It has more narrow confidence intervals despite a smaller sample size.
3. And apart from the two-year rise around 1999, the FIBSI demonstrated a relatively steady and modest rising trend, since 1992.

Thus the (1) inexplicably large yearly variation in DBSI (2) unexpectedly wide CI's, and (3) arguably qualitative difference in the story it tells about the recent change in egg production over time compared to the FIBSI, indicate a problem with the FIBSI index in Zone C in recent years. Norm Hall's report made a similar point, emphasising the difference observed in recent years between FIBSI and FDBSI.

In the northern Zone B, there is no sign of an upturn in the fishery-independent BSI in the last couple years, which is evident in the DBSI.

The problem(s) with DBSI could possibly lie in the raw data, or it could be something in the GLM model analysis which causes yearly variation to increase, and possibly also the relatively wide CI's. Therefore, it would be useful to know whether these problems are evident in the raw observer DBSI data. If not, this would imply they were introduced by the GLM. Other causes may be investigated.

These anomalies, the high yearly variation, the wide confidence intervals, and the divergence in recent trend and in amount of yearly variation compared with the FIBSI, do, I believe, call into question the FDBSI as the basis for management decision making. It would not, on that basis, appear to be a sufficiently reliable measure.

Was the 3-year moving average introduced to smooth this yearly variation? If so, the use of the 3-year moving average is also less than ideal. Under such high annual harvest rates in the neighbourhood of 70-90%, there are easily-imagined scenarios of rapid stock decline where management response cannot afford to wait an additional year or two to know if egg production has genuinely declined well below safe levels, awaiting the 3 years of data needed for 3-year averaging. Rather, decision rule application and management decision making would be better served by an index whose yearly value alone was a reliable measure of changes in stock abundance, and specifically, of egg production.

Given the high quality and quantity of data for this lobster fishery, this objective of a reliable yearly index, can probably be met, as it is, in theory at least, in most fisheries worldwide. Several questions then arise:

1. If raw data do not exhibit these anomalies, or do so less, can a modified analysis, possibly a different GLM model, or some other way to analyse the fishery dependent data be constructed?

2. Do the model outputs more closely agree with the fishery-independent index?
3. Do the model outputs show the large yearly variations in Zone C?

The answers to these questions will inform decisions about how to address the current problems with the fishery-dependent spawning stock index. In particular, they will assist the determination of whether a model-based index will perform better?

It is possible that the anomalies with the fishery-independent index result from it being dependent on changing patterns of commercial harvesting. For this reason, the fishery-independent measure may be more reliable, based on its more narrow confidence intervals, relatively low variation from year to year, and the fact that it is not altered by changes in commercial fishing practices.

Yield-per-recruit

I suggest that yield per recruit analyses be undertaken in the 3 zones. This is 'old hat', requiring a smaller data input than an integrated model. However, for both economic and sustainability reasons, yield per recruit remains a quite robust and informative measure of whether a stock is growth overfished. Moreover, at the same time, it would be worthwhile, and probably not much more additional work, to assess egg-per-recruit and value-per-recruit.

Value-per-recruit seeks to quantify the monetary yield of each recruited lobster, incorporating the variation in price with landed size and month. Yield- and value-per-recruit often show a clear maximum with respect to changing harvest levels (and/or size limits). They thereby provide one criterion (among others) to assess what levels of harvest rate are optimal, something that is plainly challenging when the objective is stock sustainability, where more eggs will always give a lower risk of recruitment overfishing. Per-recruit analyses can be programmed into the stock assessment model, now under development, or simply make use of its outputs (e.g. F).

TOR 2: To review a model that has recently been developed by the Department of Fisheries (WA) for use in providing management advice for the western rock lobster fishery and propose future directions for that work

Integrated stock assessment model.

I endorse the recommendation of the MSC reviewers to produce an integrated stock assessment model. This will, as Prof Hall indicates, permit the stock indices on which management decisions are based, to use all available information, that is, to combine all data sources, when drawing inferences about harvest rates and breeding stock. It will also estimate them as absolute rather than relative levels, and infer how they and the underlying stock structure change over time.

Whether the model indices should be adopted as replacements for the empirical breeding stock indices, by incorporating all the data used to estimate them, or not, depends on model output evaluation, which should be undertaken before the model is fully adopted. In the meantime, both sources of indicators can be generated and presented in parallel, as Malcolm Haddon suggested.

Changes to the model

After considerable discussion among panel members, and with Peter Stephenson, the stock assessment modeller, major changes to the model have been implemented this week. These include:

1. The explicit dynamic accounting for numbers by length.

2. The associated replacement of the age-based growth description with length-transition matrices, which are used in all other lobster models in Australia and New Zealand.
3. Revising the survival equation to be standard Baranov.
4. Fitting to puerulus data.
5. The technical details of the model improvements are summarised by the report of Jim Ianelli, who programmed these changes.

Advantages of retaining both a length- and age-based description for younger lobsters

Jim Ianelli and Peter Stephenson are, when last I heard, re-coding the model to represent lobster population numbers by both age and length for the 2, 3 and 4 year olds (length only for 5+'s).

Retaining the ages of the younger model lobsters resolves a major source of uncertainty facing some length-based fishery models of how to allocate the lobster numbers by length bin for each yearly recruitment year class as each cohort is created in the model. For WA lobsters, these distributions by length for each puerulus settlement year class as they reach age 2 are known from the highly informative puerulus data and because of the early age at which exploitation begins.

Also, the lag in time between puerulus and recruitment is also much more precisely specified in the model when ages for younger lobsters are retained. These lags are currently inferred in a way that the model can implicitly also incorporate.

For these two reasons (distribution of recruits by length, and time lag), retaining age structure (along with length) for the early ages will also provide a potentially better estimator of yearly catches overall, and a better predictor, for future stock projections, based on puerulus.

Economic modelling

I endorse the need for economic modelling. We were informed this week that rising costs of fishing currently constitute the main threat to financial earnings of this industry. At some future stage, it may be desirable to integrate the dynamic fishery model with economics, to provide a dynamic description of economics. This will permit the model to evaluate the economic impacts on net earnings of various future effort reductions (or if ever adopted, of quota), which the current (implicitly equilibrium?) economic model might have difficulty simulating, or which it must, otherwise, duplicate.

Model catchability variation

It would be informative to try and plug in (say one region at a time) the intriguing estimates of yearly variation in catchability (efficiency) derived by Ian Wright using the depletion estimator. The depletion estimates produced quite different results for the estimates of variation in efficiency over time than are currently assumed in this (and nearly all other fisheries) of a constant 1-2% yearly exponential rise. These higher average yearly rates of efficiency gain from the depletion estimator than those currently assumed, which also show substantial increases and some quite striking decreases over time, could, or probably will substantially affect model outputs. The fact that these depletion efficiency estimates vary relatively smoothly over time (shown in Ian Wright's Powerpoint slides), also adds considerably to the credence of this analysis. The reliability of these yearly depletion estimates of harvest rate and efficiency is also supported by the notably and surprisingly straight lines of CPUE versus biomass removed by month, from March to May in most of those years.

TOR 3: To review the current western rock lobster harvest strategy and if necessary recommend improvements to it

High exploitation levels

I noted the exceptionally high harvest levels as a matter of some concern during workshop discussion. However, noting that this harvest rate excludes undersize, setose females, and over-size females, the threat to sustainability is less severe than a 70-90% percentage removed would otherwise imply. Sustainability is the principal objective of all current stock assessment and management in WA lobster.

Medium-term future

The medium-term future for this resource is currently not bright. Fishers in the meeting, notably John Fitzhardinge, felt exploitation levels to be excessively high. In addition, recruitment in the next few years of puerulus settlement, due to the long El Nino just passed, are predicted to be low for about 3 years. Thus, the recent package of effort reduction appears to have been timely.

Economic over-fishing

If sustainability is being carefully monitored, and assuming that egg production will be sufficient, and spawning females sufficiently well protected to weather a 3-year period of unusually low recruitment, then economic over-fishing remains a principal management concern. As John Fitzhardinge and Steve Gill emphasised, high costs, and a high dollar, and are greatly reducing net returns to license holders, and thus, to the State. Since sustainability is enhanced by most measures undertaken to reduce fishing costs, by reducing total levels of effort, the principal objective of sustainability is also perpetuated together with the financial objective of fishing cost reduction.

I also concur with John Fitzhardinge, and the model can test this hypothesis, that total yearly catch will be only marginally affected by the 10% and 15% reductions in effort. Instead it will take a month or two more to remove most of the recruits that arrive in each moult. In fact yield-per-recruit considerations may imply that catch could even rise modestly with lower harvest rates, especially for the more southerly regions where growth is faster for lobsters above legal size. Thus, for both economic and sustainability reasons, further effort reductions may be warranted, if recruitment declines as predicts.

Carbon emissions

The price of diesel is likely to rise in about 3 years time, if not before, with the introduction of carbon credits in Australia. This would make fishing still more costly. The statistic reported by Andrew Winzer, that fuel use has more than doubled since 1990 in WA lobster is notable, and surprising. It would certainly be consistent with estimates of increased catchability (efficiency), and with rising fuel costs. It might be interesting to calculate and report this index more regularly, since rising costs and catching power are important in this effort-regulated fishery. This would also be of interest for the proposed economic analysis.

Adding a second indicator for harvest rate

Chapter 6 of the stock assessment document proposed the addition of a second formal index for stock management decision making, of harvest rate, in addition to the existing index of breeding stock. Economic and sustainability objectives are both directly influenced by the fraction harvested. Chapter 6 specifically seeks to address the critical objective of economic return to license holders by considering fishing costs in the management and stock assessment of this resource. Previously, only sustainability considerations were an explicit aspect of WA Fisheries brief, economics being left to industry. But plainly, to reduce costs in an effort-based management regime, as Nick Caputi noted, reductions in fishing levels can only be achieved if they are 'corporate decisions', meaning all fishers must comply, and this means that they must be regulated by management decision making.

Because reducing fishing costs is a high priority objective in this fishery, I would endorse the adoption of harvest rate as the authors propose. Yearly estimates of harvest rate can come from either the existing depletion estimator, or as future model output.

TOR 4: To review Professor Hall's report and recommendations on the 2004 and 2005 western rock lobster assessment process

I found Prof. Hall's report to be comprehensive and well informed. I believe it addressed all of the MSC conditions of certification, both in broad and detailed evaluation. Most of the recommendations of Prof Hall have now been addressed:

1. An integrated stock assessment model is now being produced.
2. A stock assessment report is now drafted.
3. Quantifying the uncertainty in assessment estimates will be most effectively addressed by the development of the integrated stock assessment model, now underway

Significant management actions to reduce total allowable effort have been implemented since 2005 in all three zones.

It perhaps notable that many of these actions were undertaken, and funded, to address recommendations of the MSC accreditation process. Thus, as an external mechanism of review, and with its requirement to meet high standards of modelling, assessment, and management, the MSC process appears to have been a significant factor in accelerating these outcomes. As such, it appears to play an important function in the management and sustainability of this resource.

Summary

Three main observations are salient: (1) The fishery-dependent BSI shows three essentially independent inconsistencies, in Zone C for the last 6 years. (2) The model shows good promise of providing indices based on all the data. (3) The addition of a second management index, of harvest rate, offers a tool for objectives of both sustainability and financial return.

A lowered harvest rate might bring only modestly higher egg production (females protected in other ways), but could bring substantial savings in fishery costs, and thus, potentially, a much more substantial increase in net returns. Total catch would probably be relatively unchanged with a lower harvest rate, and by yield-per-recruit considerations, it could increase.

Professor Hall's MSC review provides a well-written, detailed and comprehensive evaluation of this fishery and its (2004 and 2005) stock assessments.

Dr. Paul Breen

Western Rock Lobster Stock Assessment and Harvest Strategy Review (16 - 20 July 2007)

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20 July 2007

This review was commissioned by the Western Australian Department of Fisheries, with the Terms of Reference shown in Appendix 1. The review is based on three documents listed in Appendix 2 plus some additional information in various reports, presentations made at the review workshop during the week of 16 July and discussions with researchers and colleagues.

In what follows, italics denote a quotation. Opinions expressed are mine and not necessarily those of NIWA. Acronyms used are: BSI breeding stock index, CPUE catch per unit of effort, FDBSI fishery-dependent breeding stock index, FIBSI fishery-independent breeding stock index, MSC Marine stewardship Certification, WAF Western Australian Department of Fisheries.

1. Stock assessment

To review the current western rock lobster stock assessment process and proposed future research.

This section will address points involving first the data and associated analyses, then the process. The new assessment model is discussed in the next section.

Data - general

The review workshop covered the fishery data and associated analyses in considerable detail. By any standards there is an impressive amount of data, and the data sets include the critical elements - catch, effort, catch rate, length structure, breeding data, tag-recapture data that gives information on growth and movements. Most aspects of the basic biology are well understood.

Some analyses use the estimated rate of increase in effective effort, given in Table 5.1 of the assessment report. For instance, the FDBSI and juvenile abundance indices are corrected to account for this. Because the recent values in Table 5.1 are not based on rigorous recent estimates and *need to be reviewed based on the depletion analysis estimates*, I suggest a) that all indices be reported as values obtained before any correction for effort efficiency, b) that these uncorrected values be used as the model input and c) that effort efficiency changes be estimated by the model.

The results of analyses of the time series of data should not be overly complex. In several places the analyses are adjusted or scaled: this removes the observational quality of the data and should be done cautiously. Here is an example from page 14 of the Hall review report:

The [FIBSI] values are then multiplied by a common factor such that the value of *the index for the 1992/93 spawning season is equivalent to the average of the fishery-dependent indices of egg production for the north (Zone B) and south (Zone C) coasts.*

Three-year moving means are useful for smoothing the data to see trends, but the raw values and their variability are important, and should always be presented in addition to the smoothed values. A mean value may be required for the FDBSI if that is used in the decision rule.

Catch

Commercial catch, by the 16 areas used by the new spatially-explicit model, are obtained from the compulsory information supplied by fishers, and then divided into the inshore/offshore components of each transect by using proportions of catch at depth reported in the voluntary logbooks. The Hall report identifies some ambiguity with respect to how that is done: this should be resolved.

Recreational catch is less well estimated from recreational surveys. The assessment should consider recreational catch explicitly -- projections should incorporate the full 5% allocation -- but recreational catches are less than 5% of the total catch, so refining these estimates should be a relatively low priority. The recreational catch inshore may be an issue in some transects adjacent to population centres. [Recreational size structure and catch rate will be difficult to characterise effectively enough and should also have a low priority.]

Catch rate

There are four data sets that involve catch rate: the compulsory commercial data, the voluntary logbooks, the commercial catch monitoring (observer catch sampling) and the research fishing (fishery-independent sampling).

Treatment of catch rate data (number or mass per pot) is variable. Most is standardised, but there is scope for some improvement. First, the list of standardisation factors appears to vary among the data sets. For instance, swell is used for some but not others; temperature was used to standardise commercial catch rate in the depletion study (Wright et al. 2006), but is not used for other data sets, and so. There may be a gain in the estimation of year effect from using all the possible standardisation factors for each data set (it is accepted that not all are applicable to every data set and that this might not be possible in some cases).

Second, there is some overlap in time and space among the four catch rate data sets. Thus, standardisation factors that are common should have the same effect on the different data sets. I recommend exploring an integrated standardisation, in which the whole set of standardisation variables is estimated by fitting to all the data sets simultaneously. This would produce better estimates of the effects of factors and better estimates of the year effects. There may be practicality problems, but this should be at least considered.

Length composition of the population

These are available from the observer catch sampling and fishery-independent survey data sets. They are of extremely high importance to the model, and protocols for their collection should be revisited and measuring target numbers reconsidered.

These two data sources were not designed to sample the population in proportion to abundance or catch. The fishery-independent survey fishes a standard set of locations while the observer catch sampling has been conducted from four or six basic ports and is stratified to cover four depths.

The model should be fitted to population size structure data. WAF must consider how best to modify, adapt or expand these extant programs to address representativeness of size frequency data. In South Australia, Tasmania and New Zealand, length data are collected by fishers in voluntary programs that measure a small proportion of the pot catches extensively over time and space. In New Zealand the data compare favourably with observer catch sampling but are considered more representative of the true catch because of the extensive nature of this sampling. Cost to the industry is much reduced compared with observer catch sampling.

Grade data from processors are available and were discussed in the review workshop. The spatial scale of the data is suspect, and the data may be best applicable to the fishery as a whole. These are important data, and the model should fit to them.

Egg production

The FDBSI is calculated from female catch rate and size structure, using fixed maturity ogives, whereas the FIBSI is based on maturity calculated from the fishery-independent survey observations. This is one of several reasons that the FDBSI and FIBSI may differ. The maturity ogive is very important to the model's results because of the high exploitation rates and the protection afforded to females by maturity. For these reasons, a better representation of maturity should be used. The two indices should be based on the same maturity curves, and in turn these should be based on the best available information, including maturity observations from the observer sampling.

The two BSI series differ in their recent values. A small project should work out why this is by separating the elements: female catch rate and size structure, maturity and fecundity. They should not be presented to the model for fitting as if they were different estimates of the same thing.

Depletion study

The depletion study is very important because it provides estimates of harvest intensity and changes in catchability. The Hall report and the review workshop identified a number of areas where further work should be done, with which I concur:

- precision might be improved;
- sensitivity to error structures should be explored;
- natural mortality should be included;
- the exclusion of some months is arbitrary and this should be made more rigorous.

Results of the depletion model should be presented as raw values, not as moving averages. The model is fitted to the same catch and effort data that were used in the depletion study, and has access to the standardisation data, so ideally the depletion estimates and catchability changes could be estimated by the model.

Puerulus data

The fine-scale catch prediction study was very convincing with respect to the predictive potential of the puerulus data. As pointed out, its value is not in the improvements to predictive relations but in the biological insights afforded: growth, temperature vs. catchability and density-dependent juvenile mortality. This work should be used in the model.

Implications of lobster size changes

Information presented at the review workshop was convincing on the questions of egg size implications and mating size implications: no relations were seen that would cause managers to be concerned about the effect of the fishery.

Data deficiencies

Some apparent deficiencies in the state of knowledge about the fishery include:

- natural mortality rate (extremely hard to measure in the field);
- handling mortality: the incidental mortality of lobsters returned to the sea, such as undersized and setose (quite difficult to estimate);
- pot selectivity with respect to size; and
- gear saturation effects.

Assessment process

The past assessment was based mostly on examination of trends in time series of fishery data. This differs from a conventional modern assessment, where a simulation model is fitted to the data with mathematical techniques, the state of the stock is explored and the stock is projected several years into the future under the *status quo* management and perhaps under different management scenarios. Sensitivity trials are then conducted to see what effects the critical modelling decisions or data uncertainties have on the answers.

Using an appropriate handling of the uncertainty such as likelihood profiles, bootstrapping or posterior distributions of derived parameters, such an assessment can be explicitly aimed at answering: what is the probability that the stock is above a limit reference point, and target and threshold reference points, and what is the probability under the *status quo* that the stock will be above a limit reference point, and target and threshold reference points, in three (or five) years?

This type of stock assessment should be the target of development of the new integrated model.

The assessment and management change cycle could be made more formal, on perhaps a three-year pattern. This would safeguard the scientists' time from unexpected diversion, give good lead time for data preparation, and would assist industry's ability to plan.

As suggested by the Hall review report, all components of the assessment - data, model, base case results, diagnostics and sensitivity trials - should be described comprehensively in a technical report aimed at the technical audience, and ideally published as a fisheries technical report. This is easiest to write as the assessment progresses. The document prepared for the review workshop was a good start at such a comprehensive document.

A second, shorter and far less technical document should be prepared for the industry and non-technical stakeholders.

[There is a high level of contact with industry and information transfer to industry, with at least an annual roadshow, and more recent more frequent rounds of coastal meetings. This is laudable.]

Peer review: the level of peer review of the scientific work is reasonably high. Peer review of the analyses and assessments consists of internal review within WAF, formal review of primary publications, review by industry during roadshows, periodic involvement of industry consultants and of course MSC reviews. My only suggestion is that peer and industry involvement during the assessment itself would be of benefit encouraged. This occurs in New Zealand stock assessment working group process, attended by industry scientists, and leads to unquestionably better assessments.

2. Model review

To review a model that has recently been developed by the Department of Fisheries (WA) for use in providing management advice for the western rock lobster fishery and to propose future directions for that work.

The review workshop discussed the new integrated model project and was shown some very preliminary results. We had extensive discussions of model structure, after which some technical changes were made. These will allow incorporation of some valuable information about the relative composition of 3- and 4-yr-old animals, but at the same time base the dynamics on length.

The model is at an early stage, and beyond saying that it appears to be headed in the right direction and shows promise there is limited scope for a review.

Instead, two general comments are offered.

First, the model should be an integrated model that uses as much of the extensive data sets as possible. Integrated means that analyses of data are made within the model - the opposite is the segregated modelling approach where data are analysed outside the model and the results are given to the model as if they were data. An example is the tagging data: the growth parameters could be estimated outside the model and the values given to the model. The integrated approach is to estimate the growth parameters from all the data within the model.

The integrated approach has these advantages:

- assumptions are consistent (in the segregated approach they often differ between the model and the data analysis);
- uncertainty in the data is propagated correctly, whereas it is lost in the segregated approach; and
- the covariance among parameters is handled correctly.

The depletion analysis is a segregated approach that could be integrated; the fine-scale catch prediction might be integrated; the BSI could be calculated in the model. Effort efficiency increase is a process that should be estimated within the model, with early work being used to suggest priors.

Second, as much of the data as possible should be incorporated into the model. Some way of weighting the data sets objectively should be developed so that the poorly estimated data is given lower weighting.

Development of the model will be a big project. Development should be seen as an evolution: a few data sets should be fitted initially, and others added as the model testing progresses. Some processes can be omitted from the initial model and added later (selectivity might be an example). It is important for WAF and the industry to recognise that the integrated model will take considerable time to build and test and refine, and thus a final version cannot be expected on a short or predictable timeframe.

Other modelling comments

The movement results shown from the early model version showed a sensitivity to movement parameters when these were constrained by flat-topped priors. It may be useful to use uniform priors on movement rates between zero and one in the first instance to see what information in the data suggests.

Consider using the tag-recapture data to assist in estimating movements. Also on tag-recapture data, the treatment of outliers is important. Whether zeroes and negative increments are removed may have a large effect on the resulting growth estimates. This issue depends on the data collection. Robust likelihood for fitting these data could be considered.

The model is assuming a constant non-setose proportion after the March moult. With the high exploitation rates suggested during the review workshop, this assumption may have strong effects on the results, and the modellers should consider alternatives.

Changes in the model's maturity schedule may also have strong effects on model results because of high exploitation rates and the protection afforded by pleopodal setae. Evidence was presented during the review that the maturity schedule has changed over time. The modellers should address this, either by developing a series of maturity schedules that apply to different stanzas of the period modelled, or (preferably) by estimating maturity from the fishery-independent sampling.

A third assumption that has strong effects because of high exploitation rates is handling mortality. The early version of the model assumed none. Handling mortality is difficult to estimate. It is probably not excessively high because fishers sort directly from the pot back into the water and surface exposure is minimal. Despite that, a 5% mortality could be significant. Handling mortality should be incorporated into the model and sensitivity trials used to explore its possible effects.

The current plan is to fit to a BSI calculated outside the model. Elsewhere I suggest that the BSI should not be corrected for effort efficiency, which should be estimated by the model. The BSI is the product of standardised female catch rate, the maturity schedule and the fecundity relation. The fecundity relation is fixed, and maturity should be estimated by the model from the fishery-independent survey data. An alternative to fitting to BSI is therefore to fit the model to the catch rate and size structure of females.

Selectivity was identified as a process that might be important to the model. The FDBSI is based on female catch rate from commercial pots, which have a selectivity curve that excludes some smaller females [this is one of several possible reasons that the FDBSI and FIBSI differ]. Because some mature females are small enough to be selected imperfectly because of escape gaps, especially in the north, the model fit to FDBSI will be affected by the lack of a selectivity curve. the curve could be estimated inside the model by fitting to the female catch rate from catch monitoring (as I think should be done).

Selectivity also affects the juvenile abundance index derived from commercial catch monitoring. As the model evolves, these data should be used in fitting the model.

Pot saturation should be considered. Industry suggested at the review workshop that this occurs now, and that removing a small amount of effort would not reduce real effort because of saturation. This should be considered.

The model's output should show the sublegal, vulnerable and protected portions of the stock in trajectories. Because at present a high proportion of the stock is protected by the MLS or maturity regulations, showing the vulnerable stock trajectory alone would be misleading.

3. Harvest strategy

To review the current western rock lobster harvest strategy and if necessary recommend improvements to it.

The currently proposed biological reference point is based on breeding stock index and is proposed to be the 1980 level. The Hall report describes some confusion about whether this should really be the 1980 level or some percentage of the unfished value.

In many jurisdictions the latter approach is used, with 20% B0 being a common reference level. Problems with this theoretical approach are:

- B0 and other unfished levels are never known directly (data are not collected when there is no fishery);
- B0 and other unfished levels can be estimated only under some assumption about density-dependence in biological process, or the lack of it, and these assumptions are rarely based on good data;
- even under the assumptions, B0 is difficult to estimate: uncertainty is very high compared with that around stock levels associated with data.

For all these reasons, an empirical reference point is preferable. The 1980 level of BSI is defensible because the fishery has often been above it, the fishery has recovered from positions below it, and this reference point should maintain egg production at levels high enough to ensure sustainability.

At the present, the decision rule approach presented to the review workshop was good. This showed the phase surface of harvest rate against breeding stock index, with estimates of historical locations on this surface.

Once sustainability is assured (but for now sustainability should be the immediate focus), there are many alternative goals of the harvest strategy. New Zealand fishers vary among areas in their defined goals: one area would like stability of catch, even if the catch is less than MSY; another area would like to fish hard when abundance is high and less when abundance is low; still another wants abundance to be kept high to keep costs low and maximise the fishing options.

At the stage where sustainability is assured, stock assessment scientists shouldn't be involved in choosing the goals of harvest strategies. Whether economic considerations should be involved depends on how the legislation is worded and on the views of government.

That said, it seems obvious that costs are high and increasing while the stock is low and likely to decrease. Fishers should consider fishing less (reducing effort) to promote stock increase stock size and thus catching rate in the medium term, in turn reducing costs.

In the long term, true decision rules should be developed and tested with the new assessment model. True decision rules have these properties:

- the goals of the decision rule are clearly defined;
- the inputs to the rule are clearly specified;
- the rule output is specific and quantitative; and
- the rule is chosen from a large number of candidate rules after extensive simulation testing with an operating model.

The goals must involve sustainability (very low risk of the breeding stock index falling below some agreed value) and might involve abundance (CPUE averaging some agreed value) or catch (average catch of some agreed value); once sustainability is attained then these goals are the domain of fishers and managers.

The inputs might be CPUE or BSI or harvest rate estimates or some combination, as long as they are clearly defined and used in rule testing. The outputs must be specific: outputs such as "reduce effort by at least 5%" or "a stock assessment will be triggered" are not specific; the rule should be a mathematical statement of what the management action will be.

Rule testing such as described usually involves an assessment model, such as the new integrated model being developed for WA, and millions of runs. There are many examples of such rules in the literature. Rules should be testing by evaluation how often they violate the limits and how often they achieve the agreed goals.

4. Professor Hall's report

To review Professor Hall's report and recommendations on the 2004 and 2005 western rock lobster assessment process.

Professor Hall's review was commissioned by the Western Australian Fishing Industry Council in response to concerns by the MSC's certifier.

The Hall report commented, as he was asked to do, on the 2005-06 stock assessment: in this review of the review I think it is most useful to focus on recommendations useful for the development of future work. However, it is recorded that I endorse this stock assessment summary from the Hall report:

> *In its Final Surveillance Report, Scientific Certification Systems Inc. (2005) noted inconsistency between the results of the stock assessment and the recommended management measures. I believe that, given the information available, the management response for both zones was appropriate, precautionary, and consistent with the decision framework. However, it is possible that, had the results of a reliable, integrated fishery model been available and the implications of uncertainty been explored fully, management measures that were more precautionary might have been recommended.*

The Hall report's review is very detailed and touches most of the items that I identified as worthy of comment during the review workshop. His grasp of the intricate technical details, especially with respect to the data sets and analyses done on them, is far greater than an outside reviewer could hope to develop in the time available. Thus, as an independent review, this one is extraordinarily well researched. I believe that the report is a valuable resource for WA Fisheries.

The Hall report makes a substantial number of recommendations, some of which have been addressed and many of which are planned to be addressed in the near future.

Some of the Hall recommendations that have especially high resonance with me are as follows: the underlined sections are a paraphrase of actual recommendations made in the Hall report and any text in italics are a direct quote.

<u>Data not always as well documented as they should be</u> - protocols and analytical procedures should be clearly described. An example from the report is the discussion on page 8 of the Hall report, concerning a lack of clarity with respect to dividing the commercial catch and effort into depth zones based on the voluntary logbook data. Given the reliability of the model on the catch by depth zone, this is a critical procedure and must be described adequately.

<u>Diagnostic methods should be developed and applied to data sets</u> to determine their reliability. There are many data sets, and some are inconsistent with others; some are used formally and others are not. The integrated model should evolve towards considering all data sources, and for that some critical exploration of data reliability will be required.

<u>Uncertainties associated with data should always be estimated and presented</u>.

Data should be tabulated in the technical documents - Norm Hall specifically mentions the standardised effort data, but this should apply to all data.

The depletion estimates should be explored further, especially with respect to how sensitive the results are to the assumptions made and procedures used. The depletion estimates comprise important evidence about the possibly very high exploitation rates in this fishery, and the method must therefore be robust. [In the long term, depletion should be estimated from the model results using the same approach].

The data are imprecise but trends will become more reliable in the long term. I do not like three-year moving means, and my suggestion is that data and results of analyses should be always presented in raw form as well. Trends in noisy data are hard to detect reliably.

An integrated model should be developed and fitted to most of the data available, including length and grade data. This is of very high importance and is discussed in the review above.

Two kinds of documentation are required: one set that is comprehensible for fishers

and one set that is comprehensive for technical review. Hall's report suggests that WA could follow the South Australian model of a "living document" that is upgraded when a new assessment is made.

Future assessments should be more objective and should consider the precision of the data and the uncertainty that may be present. This recommendation is discussed above: the assessment should evolve towards an integrated consideration of all the data available, and should present the risks associated with stock being below specified limit, target and perhaps threshold levels.

An assessment checklist should be used. It suggests that the MSC principles could be used as the basis for this, and presents a draft version of such a checklist, but also mentions the NRC checklist used in the USA.

In the draft checklist presented in Hall's report, I would increase the priority of several items: these include the commercial catch data, the processor grade data, length frequency data, voluntary logbook data and handling mortality, all of which are discussed elsewhere in this review. I would especially endorse the high or very high priority that he gives to analysing the tag-recapture data for growth, developing the integrated model and improving understanding of natural mortality.

Reference points need to be revised. This is discussed elsewhere in this review. The Hall report discusses the confusion caused if it is unclear whether the biological reference point based on egg production is an empirical reference point (the 1980 value) or a theoretical value (some percentage of the unfished level). I strongly recommend that WA confirm the former approach (the 1980 level), which is defensible and much better determined than the latter.

The Hall report recommends a limit reference point for fishing intensity (F, exploitation rate or harvest rate). I am not in full agreement with this: such a reference point is a possibility, but the real goals might be egg production and abundance, which are outcomes of the harvest rate. Achieving acceptable egg production and abundance will require lower harvest rates, without a need to specify harvest rate limits.

The Hall report has a large section that addresses MSC concerns. For instance,

> *The key issues in the above table are the apparent inconsistency between the trends exhibited by recent values in the time series of fisheries-dependent and independent egg production in the southern zone and the unusual trend exhibited by the time series of estimates of annual exploitation.*

The comments in this section seem authoritative but I have not had time to study the MSC report and have not reviewed these comments carefully.

5. Status of the stock

Although this was not a term of reference, reviewers were invited to comment if we wished.

The stock seems likely to be highly exploited. I base this comment on the depletion study results, estimates presented by WAF and comments from fishermen during the review workshop.

At the same time, the stock as a whole must be remarkably resilient to have recovered from high exploitation rates and low female protection in the past.

The issue at present is how heavily exploited the stock is, and whether recent increases in effort effectiveness are masking decreases in the stock. Common ground is that:

- harvest rates on vulnerable fish are high;
- egg production is either near the limit reference (North) or is declining (South);
- predicted recruitment is lower than average based on puerulus estimates; and
- effort levels should probably be reduced for both safety and economic effects.

Some disagreement is evident between scientists and the industry. The view expressed by portions of the industry is this (in my paraphrasing):

- efficiency has increased faster than the rate used by WAF to correct various indices;
- pot saturation is marked and small reductions in effort will have no effect on catch;
- current fishing is decreasing the deep stock size and the decrease is masked by the increased q; and
- the fishery is moving into deeper water than was fished before.

Some support for the industry view comes from the depletion analyses, which show very high rates of increase in q, and processor grade data, which show declining proportions of A grades.

Which view is correct? Ideally this should be explored with the new integrated model. In the short term, this question may be difficult to resolve, but it could be explored through inspection of trends in the independent fishing catch rates and length frequency data, and uncorrected fishery CPUE. The disagreement does not affect the need for effort reductions to move the stock to a safer place, but the amount of effort reduction required is dependent on which view is correct.

6. Some additional thoughts after the industry meeting

Effects of climate change: the limits of distribution of *P. cygnus* may be shifted south as warming takes effect?

One fisher expressed dissatisfaction at the lack of feedback from the logbook program: these are valuable data and worth some technical input into education, training, quality control and feedback, if that doesn't already occur.

Suggestion that perception surveys might be useful: I'm skeptical of perception surveys. Better to try to make direct estimates of quantities of interest.

A suggestion was made that old grade data exist specific to area: this should be chased down.

Appendix 1: Terms of reference

Terms of reference for the stock assessment expert panel.

- To review the current western rock lobster stock assessment process and proposed future research.
- To review a model that has recently been developed by the Department of Fisheries (WA) for use in providing management advice for the western rock lobster fishery and propose future directions for that work.
- To review the current western rock lobster harvest strategy and if necessary recommend improvements to it.
- To review Professor Hall's report and recommendations on the 2004 and 2005 western rock lobster assessment process.

Appendix 2: Documents used in the review. Citation does not imply publication.

Anon. 2006. Appendix 3 – action plan for meeting all required conditions identified in the 2006 re-assessment report for the Western Australia rock lobster fishery. Action plans to meet the conditions of certification. 41 pp.

Caputi, N., R. Melville-Smith, S. de Lestang, J. How, A. Thomson, P. Stephenson, I. Wright & K. Donohue. 2007. Stock Assessment for the West Coast Rock Lobster Fishery. Unpublished report to Western Rock Lobster Stock Assessment and Harvest Strategy Workshop participants. 198 pp.

Hall, N.G. 2007. Review of the 2004 and 2005 stock assessments of the Western Rock Lobster fishery. Unpublished report to the Western Australian Fishing Industry Council. 89 pp.

Wright, I., N. Caputi & J. Penn. 2006. Depletion-based population estimates for western rock lobster (*Panulirus cygnus*) fishery in Western Australia. *New Zealand Journal of Marine and Freshwater Research 40*: 107–122.

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Report on the review of W. Australian rock lobster assessment

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The review of WA rock lobster was designed to address four terms of reference and are listed in the report provided to the meeting. The ToR deal evaluating the process of the assessment and management system and the current state of research activities. The following deals with these issues to some degree but is mainly focused on ToR 2 which is:

> *"To review a model that has recently been developed by the Department of Fisheries (WA) for use in providing management advice for the western rock lobster fishery and propose future directions for that work."*

The approach taken for this review was to go through the computer code in detail and develop technical recommendations and a clear understanding on aspects of the model. These general recommendations respond to comments by the MSC review and those found in Professor's Hall's document. The following attempts to outline some specific points regarding the modelling approach. Detailed technical comments have been (and will be) relayed directly to WA Fish scientists.

Age versus size structure?

Rock lobsters, as with most crustaceans, are most suitably modelled by simply tracking numbers at size over time (as opposed to numbers at age). This is due to the fact that direct aging of these animals is difficult. Assumptions about moulting frequency and changes in size are readily available and directly applicable. Given the high quality of the puerulus data, some of the drawbacks of size-based methods (namely linkages to actual age) will be avoided. Conceptually, choosing the size-based approach will be more straightforward and require fewer assumptions and approximations than the age-based approach. The present model developments appear to be headed towards adopting a size-based approach and this should be encouraged.

Size-selectivity

It was determined that since 1975, there are 89 distinct rule combinations of size-based restrictions on retained catch. These regulations are well documented and were implemented in code (subject to further checking) during the review. A major advantage of this approach is that assumptions about size-specific selectivity are well found and do not require substantial effort for estimation purposes (fixed inputs are relatively satisfactory). An example set of size distributions of a population under different levels of fishing is given Figure 1.

Growth

WA lobster data on growth increments are available from tag data. A natural application of these data is to estimate WA rock lobster growth patterns which the WA Fisheries scientists have done by fine-scale area and sex. These two axes are considered important because of differential growth observed from north to south and because these animals exhibit sexually dimorphic growth. This information was used to develop size-specific transition matrices with code developed by the review panel and WA scientists. Illustrations of the interaction between size limits impacting mean length at "real" age (with fishing) were developed and presented (Fig. 2). Switching to a fundamentally size-based model resolves this concern since growth is a function of season and current carapace length (as opposed to age). Further research on specifying an appropriate level of variability in growth is required. Based on discussions and presentations, it became apparent that growth variability on the order of 8% was too low whereas 15% appeared to provide a reasonable "spread" of lobsters that mimicked observations.

Reproduction/stock structure

The developing model deals with fine scale geography and time for the population dynamics. The extent that this is important for reproductive potential considerations, particularly if some areas are depleted at higher levels than others (and subsequent recruitment is affected) can be evaluated. The assessment report provided a section evaluating stock-recruitment patterns for WA rock lobster. However, the "stock" values used were simply spawning biomass indices (measured with a fair amount of imprecision) and "recruits" were based on puerulus counts, also measured with significant levels of uncertainty. This errors-in-variables problem might better be evaluated within the integrated model (when it becomes available). The current document lacked figures and tables to evaluate this aspect of the present research on stock-recruitment. Clearly the environmental factors play a large role in affecting settlement rates of puerulus. This research will be aided by results from the fine-scale spatio-temporal integrated model.

Movement

WA scientists were able to provide rough estimates of the size-specific movement for lobsters. These are presented in Fig. 3 and avoid ambiguities that were involved in the age-structured approach of estimating migration rates to 3 and 4-yr old animals.

Initial conditions

Presently, the setup of the developing model made simple assumptions about initial conditions (i.e., the numbers-at-age in 1975). However, these assumptions required somewhat arbitrary specifications and were not fit to actual data. During the review, the panellists drafted computer code with WA fisheries staff that was consistent with growth, movement, and size-based selectivity factors (e.g., Fig. 4). Such a framework can be adapted to assist in the developing integrated model.

Treatment of data

The current direction of the model appropriately tunes to a variety of observations. This should continue to strive to be generalized so that more data can be used. For example, the "grade" data on the catch seems to be an important source of information on the coast-wide catch levels by size. Tagging data could be incorporated within the model to revise estimate of growth. However, for starters using estimates calculated externally will help with progress in model development aspects. Size composition by region and time steps should be used when the model is further developed. This could be used to supplement puerulus counts and the breeding stock indices. Also, while the puerulus indices are an excellent source for information on subsequent recruitment, their treatment within the model would be cleanest if considered as data rather than (with a functional form) directly linked to modelled recruitment estimates. The functional form of linking puerulus counts within the model currently involves some density dependent mortality. This approach is easily retained in the alternative approach and may be more easily evaluated relative to other uncertainties. Finally, profiling over key parameters to evaluate the impact of data components is important, but should be done after model configuration aspects are stabilized and well understood.

CPUE

The application of CPUE data to obtain annual estimates of abundance (so called depletion studies) reveals that there are data that provide robust estimates of absolute biomass. Barring issues with these data related to hyperstability, these data will similarly inform the 24 time-step integrated model that is under development.

Complex or simple?

The present model development has a good interface through excel and this provides a convenient way to organize data and easily "collapse" the model to less complex versions (e.g., with fewer regions required). The recent developments to transition to size-based should continue to have this facility. The proposed size-based model defines 81 mm "bins" (from 40mm – 120mm). This provides the structure for all size-related information (e.g., regulatory selectivities, the numbers-at-length, weight-at-length, etc). The dimension of the carapace length is quite high and a number of refinements for efficiency considerations were envisaged. This should be entertained as model developments continue so as to minimize run-time issues and added confusion.

Uncertainty

Generally, explicit assessment uncertainty is presently poorly defined. However, from interactions among scientists, stakeholders, and the managers, it is clear that uncertainties are implicitly understood and appear to be taken into account. If this were not the case, discussions and debate would be minimal. The importance of communication and interactions with stakeholders cannot be overemphasized. These interactions provide the background needed to convey model characteristics. Specific to particular data components, better clarity is needed prior to using these within the model.

Communication

Given the high resolution of the fine-scale model, it will become increasingly important to develop transparent ways to display data and model results. This is a difficult task and if inadequate attention is given, the utility of the model, however well done and evaluated, may fail.

Other comments

The "living document" that was presented to the review panel is extremely useful and greatly assisted in enabling the discussions during the week. In the present form, the document is about half way between a collection of papers and a single stand-alone document. As mentioned by others, it was somewhat light on several technical aspects and somewhat too technical for general summary information. Overall, the WA rock lobster fishery management system is world class with a highly professional approach to communicating with stakeholders and conducting the necessary research.

While model developments have apparently lagged somewhat, the current data collections and analyses provide good assurance that sound, scientifically based management decisions are being made. When the model refinements are completed, the scientific basis for management will improve incrementally. Where larger issues are confronted (e.g., the possibility of switching to an output-based system) the utility of the modelling efforts will help considerably.

Regarding an approach for going forward, exchanges among scientists involved in similar modelling approaches should be encouraged. Very similar models have been developed and are used in

S. Africa, New Zealand, and Alaska. From the Alaskan side, continuing existing and establishing new collaboration is encouraged. Office accommodation at the NMFS facility could be made available if desired, and interactions with scientists involved with modelling crabs and other species could provide assistance. The scientists at the nearby University of Washington School of fisheries also can provide some technical expertise and interactions that would be valuable.

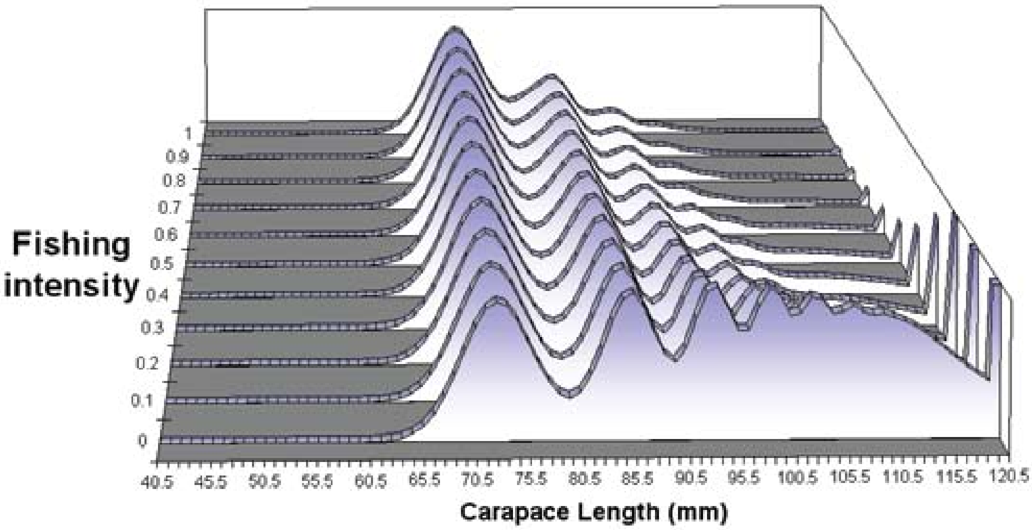

Figure 1. Patterns in a single case (Females in the inshore area 1) at different fishing mortality rates (with size-based regulations in place but no movement).

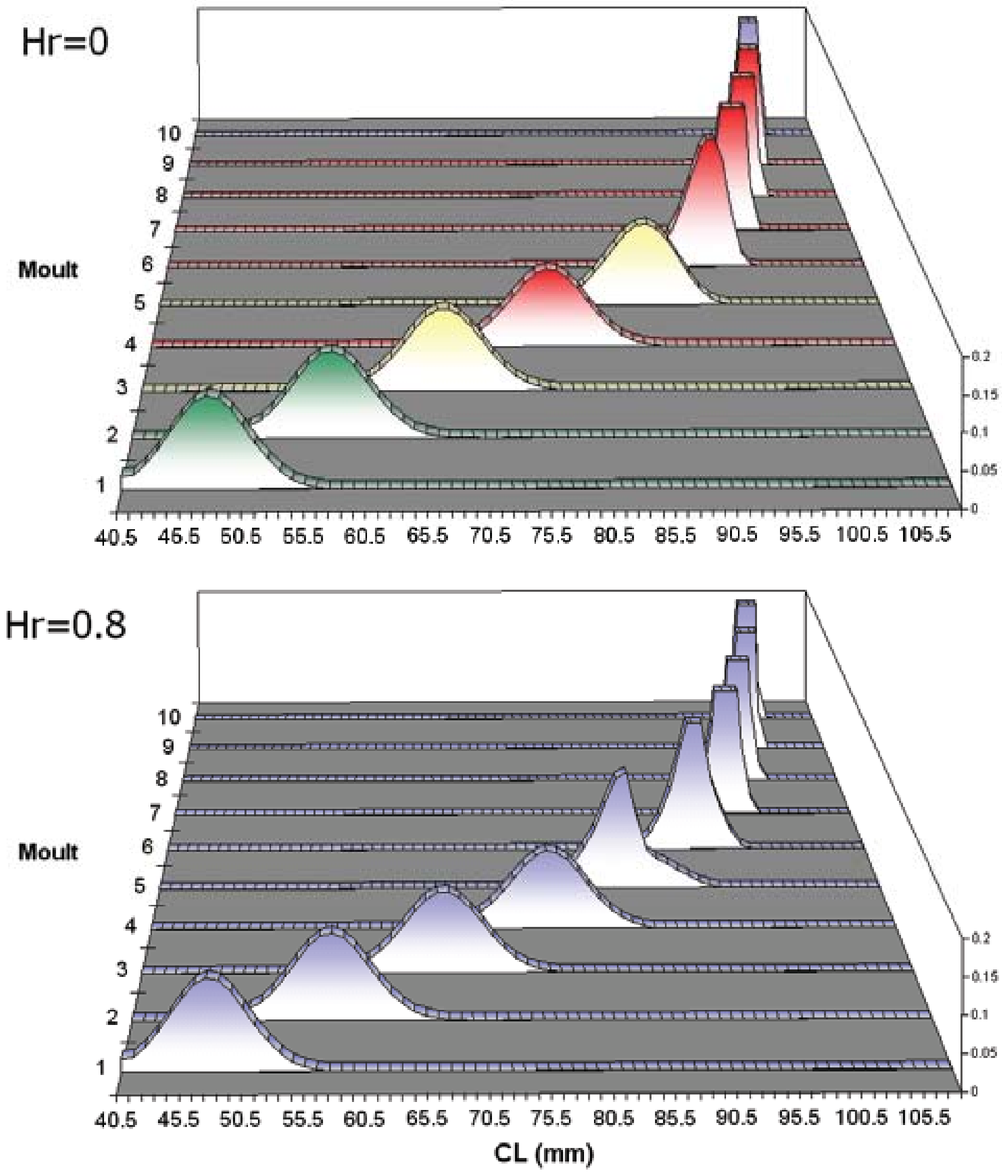

Figure 2. Illustrative presentation of growth patterns under no fishing (top panel) compared to a fished stock (bottom panel).

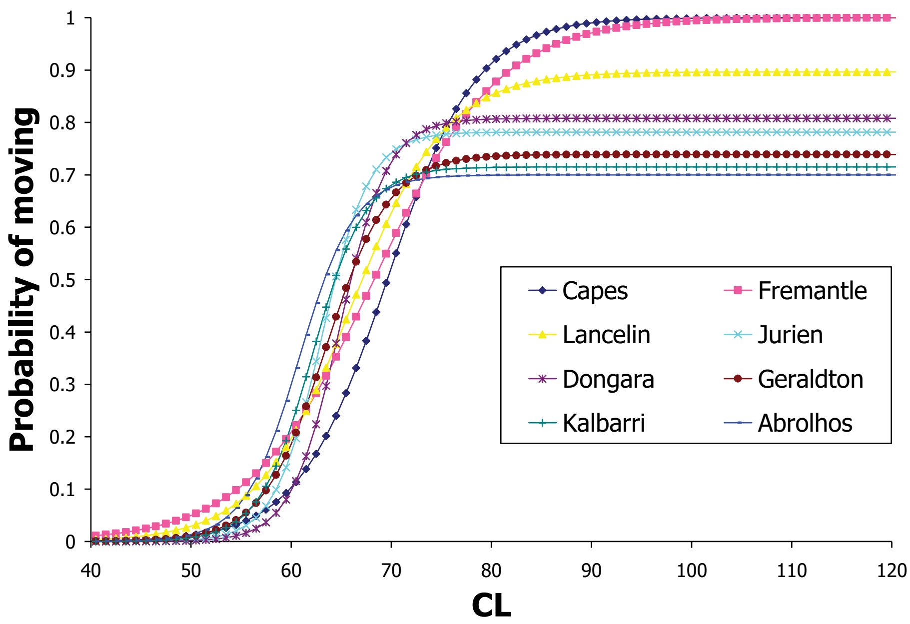

Figure 3. Estimates of length-specific movement probabilities developed for use in the the model

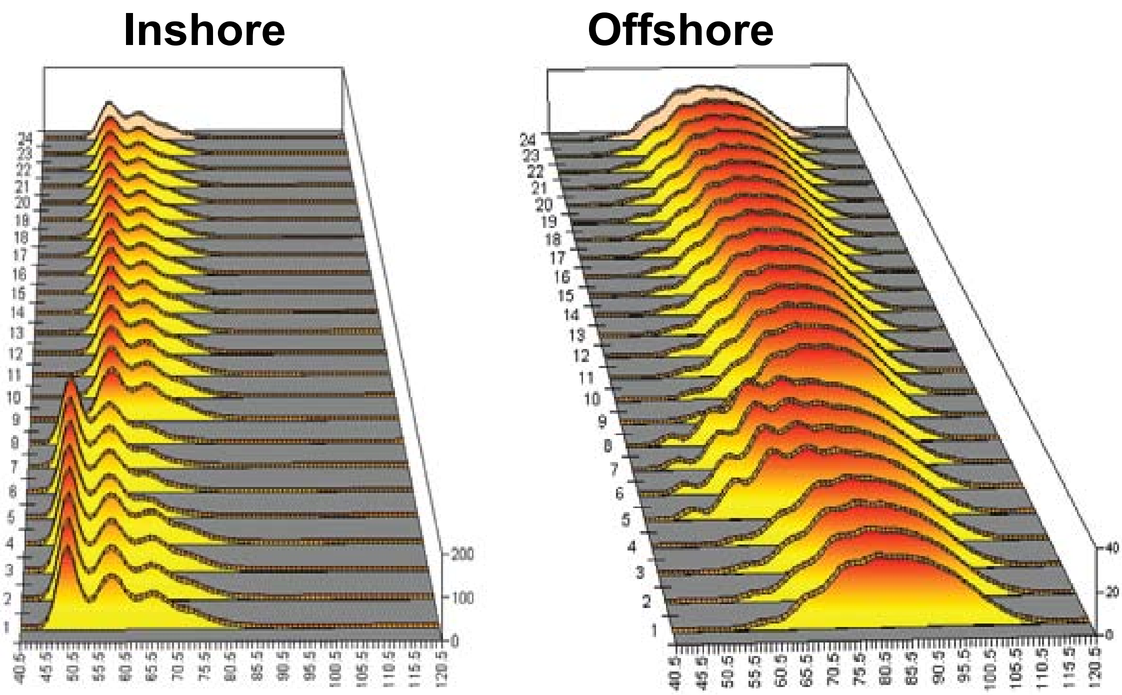

Figure 4. Characteristic patterns of WA rock lobster over 24 time steps within a single year for a nearshore area (left panel) and a contiguous offshore area (right panel) with growth and movement.

Appendices

Appendix 1 – Workshop Agenda

Date	16 - 20 July 2007 with stakeholder presentation on 20 July
Location	Western Australian Fisheries and Marine Research Laboratories Conference Room 3, 1st Floor 39 Northside Drive Hillarys, Western Australia (09) 9203 0111
Purpose	To conduct a stock assessment and harvest strategy workshop for the western rock lobster fishery, with the assistance of a panel of expert stock assessment research scientists.

Monday 16 July 2007

09:00	Welcome and objectives of the workshop – Peter Millington
09:15	Recreational stakeholder view of the workshop – Frank Prokop
09:25	Commercial stakeholder view of the workshop – Steven Gill
09:35	Biological background information - Roy Melville-Smith/Simon de Lestang
10:15	Morning tea
10:30	Management of the fishery - Kevin Donohue
11:00	Data description and time series analysis - Simon de Lestang/Nick Caputi
12:30	Lunch
13:15	Catch predictions - Simon de Lestang /Nick Caputi
14:00	Stock recruitment relationship/environmental relationships/climate change effects - Nick Caputi/Alan Pearce
14:45	Afternoon tea
15:00	Using depletion analysis to estimate exploitation rate - Ian Wright
15:45	Review progress – Peter Millington
16:15	Close

Tuesday 17 July 2007

09:00	Introduction – Peter Millington
09:10	Model biological description - Simon de Lestang Model technical aspects - Peter Stephenson Model outputs and fitting process - Peter Stephenson
10:15	Morning tea
10:45	Model future directions - Peter Stephenson and Simon de Lestang
11:45	Economic model and proposed new economic model – Nick Caputi/Neil Thomson/Steven Gill
12:30	Lunch
Afternoon:	Expert panel to have a hands on opportunity for interaction with the model – Peter Stephenson

Wednesday 18 July 2007

09:00	Current and future decision rules framework overview – Kevin Donohue/Nick Caputi
09:30	Discussion of decision rules framework – Peter Millington
10:15	Morning tea
10:30	Discussion regarding possible improvements to the decision rules framework – Peter Millington
11:30	Review workshop terms of reference 1 – Peter Millington
12:30	Lunch
13:30	Review workshop terms of reference 2 – Peter Millington
14:30	Review workshop terms of reference 3 – Peter Millington
15:30	Afternoon tea
15:45	Presentation by Professor Norm Hall of his report and recommendations regarding the 2004 and 2005 stock assessment process - Norm Hall
16:15	Review workshop terms of reference 4 – Peter Millington
17:15	Close
19:00	Workshop Dinner

Thursday 19 July 2007

All day:	Panel members write their report and prepare presentations. Informal discussions take place as necessary.

Friday 20 July 2007

09:00	Opening remarks (Chair*)
09:15	Research overview (Dr Caputi)
09:45	Presentation of workshop terms of reference 4 - one or more panel members. Discussion from the floor. (led by Dr Breen)
10:15	Morning tea
10:30	Continuation of presentation of workshop terms of reference 4 - one or more panel members. Discussion from the floor. (led by Dr Breen)
11:00	Presentation of workshop terms of reference 1 - one or more panel members (led by Dr Haddon). Discussion from the floor.
12:00	Presentation of workshop terms of reference 2 - one or more panel members (led by Dr Ianelli). Discussion from the floor.
12:30	Lunch
13:30	Continuation of presentation of workshop terms of reference 2 - one or more panel members (led by Dr Ianelli). Discussion from the floor.
14:00	Presentation of workshop terms of reference 3 - one or more panel members (led by Dr McGarvey). Discussion from the floor.
15:00	General discussion (Chair*)
15:15	Close and afternoon tea

- Chairman: Mr Peter Millington

Appendix 2 – Invitees and Attendees to the Western Rock Lobster Stock Assessment Workshop and Stakeholder Meeting (SHM)

Name	Organisation	Attended Both / SHM
Reviewers		
Paul Breen	National Institute of Water & Atmospheric Research (NZ)	Both
Malcolm Haddon	Tasmanian Aquaculture & Fisheries Institute	Both
James Ianelli	National Oceanic & Atmospheric Administration (USA)	Both
Richard McGarvey	South Australian Research & Development Institute	Both
Workshop		
Peter Millington	Department of Fisheries (WA)	Both
Rhys Brown	Department of Fisheries (WA)	Both
Nick Caputi	Department of Fisheries (WA)	Both
Kevin Donohue	Department of Fisheries (WA)	Both
Rick Fletcher	Department of Fisheries (WA)	Both
Alan Pearce	Department of Fisheries (WA)	Both
Simon de Lestang	Department of Fisheries (WA)	Both
Jason How	Department of Fisheries (WA)	Both
Neil Thomson	Department Treasury & Finance	
Ron Edwards	Rock Lobster Industry Advisory Committee Chair	Both
Steven Gill	Western Rock Lobster Council	Both
Norm Hall	Murdoch University and Department of Fisheries (WA)	Both
Guy Leyland	Western Australian Fishing Industry Council	Both
Roy Melville-Smith	Department of Fisheries (WA)	Both
Peter Stephenson	Department of Fisheries (WA)	Both
John Fitzhardinge	Western Rock Lobster Council Board/Commercial Fisher	Both
Guy Edgar	Western Rock Lobster Council Board/Commercial Fisher	SHM
Mal Millard	Western Rock Lobster Council Board/Commercial Fisher	SHM
Dexter Davies	Western Rock Lobster Council Chair	SHM
Frank Prokop	Recfishwest	Both
Richard Stevens	Rock Lobster Industry Advisory Committee R & D Sub-committee	SHM
Stakeholder Meeting		
Jim Penn	Department of Fisheries (WA)	Both
Chris Tallentire	Conservation Council of WA	–
Caitlin Barry	Department of Environment & Water	–
Melissa Geise	Department of Environment & Water	–
Paul Gamblin	World Wildlife Fund	–
Edwina Davies-Ward	Marine & Coastal Community Network	–
Kate Rogulskyj	Marine & Coastal Community Network	SHM
Lee Butcher	Dept of Environment & Water Resources	–
Chris Simpson	Dept of Environment & Conservation (WA)	–
Chet Chaffee	Scientific Certification Systems	–
Rebecca Hubbard	Wilderness Society of WA	–
Neil Loneragan	Murdoch University/ Rock Lobster Industry Advisory Committee R & D Subcommittee	SHM
Duncan Leadbetter	Marine Stewardship Council	–
Alice Hurlbatt	Western Rock Lobster Council	SHM
Ivan Spalding	Western Rock Lobster Council Board/Southwest PFA & Wetliners	SHM
Gill Waller	Rock Lobster Industry Advisory Committee R & D Subcommittee	–
Stephen Hood	WAFIC Board/RLIAC R & D Subcommittee	–
John Newby	Rock Lobster Industry Advisory Committee R & D Subcommittee	–
Darren McTaggert	Rock Lobster Industry Advisory Committee R & D Subcommittee	–
Eddy Toomey	Rock Lobster Industry Advisory Committee R & D Subcommittee	–
Clinton Moss	Western Rock Lobster Council Board	SHM

Colin Suckling	Western Rock Lobster Council Board	–
Craig McTaggert	Western Rock Lobster Council Board	–
Fred Tucker	Western Rock Lobster Council Board	–
Rod Dransfield	Western Rock Lobster Council Board	SHM
Terry Ash	Western Rock Lobster Council Board	–
Tim Dyke	Western Rock Lobster Council Board	SHM
Tony Gibson	Western Rock Lobster Development Association	–
Tim Bray	Office of the Minister for Fisheries	–
Lindsay Joll	Department of Fisheries (WA)	–
Greg Paust	Department of Fisheries (WA)/Recreational Fishing Advisory Committee member	–
Ian Curnow	Department of Fisheries (WA)	–
Tony Cappelluti	Department of Fisheries (WA)	–
Roy McVeigh	Rock Lobster Industry Advisory Committee member	–
Nick Corbo	Rock Lobster Industry Advisory Committee member	–
Tony Jurinovich	Rock Lobster Industry Advisory Committee member	SHM
Leonie Noble	Rock Lobster Industry Advisory Committee member	SHM
Jenny Shaw	Rock Lobster Industry Advisory Committee member	–
Jim Maloney	Rock Lobster Industry Advisory Committee member	–
Peter Bailey	Rock Lobster Industry Advisory Committee member	–
Des Wood	Rock Lobster Industry Advisory Committee member/Recreational Fishing Advisory Committee member	–
Chris Beissel	Rock Lobster Industry Advisory Committee member	SHM
Sam Koncurat	Rock Lobster Industry Advisory Committee member	SHM
John Cole	Rock Lobster Industry Advisory Committee member	–
Tony Smith	Commonwealth Scientific and Industry Research Organisation	–
Jim Burford	Rock Lobster Industry Advisory Committee member	SHM
Steve McLeary	Central West Coast Professional Fisherman’s Association	–
Bruce Cockman	Dongara Professional Fisherman’s Association	–
Brad Armstrong	Western Australian Rock Lobster Fishers Federation	SHM
Leonard Sgherza	Western Australian Rock Lobster Fishers Federation	SHM
Mark Atkinson	United Mid West Fishers Association	SHM
Anthony Pirrotina	Geraldton Professional Fisherman’s Association	–
Andrew Winzer	Western Rock Lobster Council	Both
Greg Hart	MG Kailis	–
Norman Halse	Recreational Fishing Advisory Committee member	–
Doug Bathgate	Recreational Fishing Advisory Committee Chair	–
Geoff Bunn	Recreational Fishing Advisory Committee member	–
Graham Cooper	Recreational Fishing Advisory Committee member	–
Jim Greig	Recreational Fishing Advisory Committee member	–
Sara Hennessy	Recreational Fishing Advisory Committee member	–
Jeni Lerch	Recreational Fishing Advisory Committee member	–
Sandra Lymbery	Recreational Fishing Advisory Committee member	–
Chris Mills	Recreational Fishing Advisory Committee member	–
Kay Webber	Recreational Fishing Advisory Committee member	–
Angus Callendar	Western Australian Fishing Industry Council Board	–
Bronwyn Harries	Western Australian Fishing Industry Council Board	–
Kim Colero	Western Australian Fishing Industry Council Board	–
Rick de San Miguel	Western Australian Fishing Industry Council Board	–
Peter Fraser	Western Australian Fishing Industry Council Board	–
Graeme Stewart	Western Australian Fishing Industry Council Board	–
Kerry Rowe	Western Australian Fishing Industry Council Board	–
Lorraine Hitch	World Wildlife Fund	–
John Looby	Department of Fisheries (WA)	No
Mike Jones	Seabird Ledge Point Professional Fisherman’s Association	SHM