Review of current and past stock assessments for the South Australian Northern Zone rock lobster fishery

NIWA Client Report: AUS2002-001
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Executive Summary

This is a report written for PIRSA by Paul Breen & John McKoy of NIWA.

The report reviews recent assessments carried out for rock lobsters (*Jasus edwardsii*) in the Northern Zone of the South Australian rock lobster fishery. It reviews the data available and the uses to which various data have been put. Recommendations are made for future data collection strategies and for enhanced use of the data currently available. The old catch and effort data could be valuable to the assessment, but are not currently used. Length frequency data are not currently used. Standardised pre-recruit indices are obtained from the voluntary catch sampling data, but the analogous CPUE is not calculated.

The report also reviews stock assessment methodology used so far for this fishery, considers proposed new methodology, and makes recommendations. An integrated assessment approach is recommended. The assessment should also present uncertainty and risk estimates, and explicitly address the requirements of the management plan.

The current state of the fishery is discussed, based on the evidence in the documentation and data provided by SARDI. A new assessment was not within the scope of the contract. With data provided to the end of the 2000-01 season, with a version of the model used by SARDI in 2000, and with a series of caveats, the fishery appears to us to be reasonably stable and in a healthy position. The pre-recruit index has a downward trend that may presage a downturn in biomass.

The recent assessment documents express concern about increased efficiency of effort and serial depletion. We think these concerns, even if well founded, are not obvious in the data nor strongly supported by the analyses provided. If the concerns are correct and effective effort has increased, then the stock has probably declined from the reference period. The best way to approach this issue is to conduct an appropriate integrated assessment.

1. Plain Language Summary

Paul Breen and John McKoy are rock lobster biologists with NIWA, a New Zealand Crown Research Institute. We were commissioned by PIRSA (through NIWA Australia) to review some specific topics with respect to the Northern Zone rock lobster fishery of South Australia.

Our first task involved reviewing the current and previous stock assessments. Our first major point in the report is that South Australia has very good biological and fishery data as a result of programs conducted in the 1990s by Jim Prescott and his colleagues.

The most recent assessment was published in 2001 by Prescott and Xiao and was based on a version of the qR model, using data from the 1999-2000 season. Another report in 2001 updates some simple summaries from the 2000-01 data, and presents a variety of analyses of effort, but this report does not really comprise a stock assessment.

We make a series of recommendations for future stock assessment work. We state that the existing stock assessment is a good start, but much more is required. We recommend that the assessment should:

- present what the Management Plan discusses as indicators and reference points,
- present uncertainty estimates around results,
- explore how well the model fits the data,
- make projections to explore risk,
- use more of the data that are available in an integrated approach,
- address important issues in the assessment and not outside,
- be better described and explained.

To comment on the state of the stocks, we built a version of the qR model and used it, with the 2000-01 data, to examine results from what a stock assessment might have looked like. We did this because there was no "current" stock assessment. This was

not a stock assessment - we would do that very differently (it was outside the scope of this project).

From the data provided, we found:

- the current rate of fishing is about 30% per year,
- CPUE has fluctuated within a restricted range in the past decade,
- the 2000-01 raw CPUE was just below that in the reference period, but was obtained from a year in which the legal size was increased,
- mean weight has been near 1.0 kg, and within a fairly narrow range, for 30 years

Taken together, we think these would indicate a generally healthy situation. **BUT** we provide a list of cautions, which include:

- the lack of uncertainty estimates in this procedure,
- use of unstandardised CPUE,
- the exclusion of important data (esp. length frequencies) that should be used in the assessment,
- the lack of future projections or risk estimates that would suggest what might happen in the near future,
- the simplicity of the qR model, which may ignore important aspects of the biology,
- possible model bias,
- the possibility of increased effective effort.

We look at the arguments for the idea that effective effort has increased and at the analyses done to explore the issue. We were impressed by the ingenuity of the analyses, but not by the results. We think that effective effort may have increased and that at some stage serial depletion might have taken place. We continue to think that the evidence is currently weak, and that the best way to approach the issue is with an integrated assessment.

If effective effort has increased since 1992, then the current state of the fishery would not be as good as that suggested by our analysis, or any analysis that uses the nominal CPUE. Outside this report, we provided advice to the FMC to illustrate this point. Under the most extreme situation we modelled, the current exploitation rate was 38%.

Thus, because of the deficiencies in the existing assessment, the uncertainty about increasing effectiveness effort and its effect on the current stock status, a better assessment is badly needed.

The pre-recruit index shows a downward trend from 1999 onwards. This suggests that biomass may decline in the short term.

SARDI's reaction to our first draft is appended, and to that we append a response. We also append the questions we asked SARDI and the answers received. A Glossary is now provided for the technical terms used in the report.

2. Terms of Reference and Review Structure

The following terms of reference were provided in the tender document for the phase of the contract addressed by this report:

Review Fishery Performance - current and previous stock assessments

1. *Review previous stock assessments and evaluate current knowledge.*
2. *Assess status of the fishery.*
3. *Comment on current knowledge and implications of broader environmental, climatic and/or oceanographic influences.*
4. *Comment on current knowledge and previous assessment of changes in the level of effective effort being expended in the fishery.*
5. *Provide review Sub-committee with a report on findings.*

Special considerations include:

- *The SA Research & Development Institute will coordinate the provision of previous stock assessments and existing data and data will be available after January 14th 2002.*
- *Cooperation will be sought from Mr Jim Prescott (AFMA), to provide information to reviewers upon request.*

- *A draft report is to be presented to Sub-committee by 15th February.* [subsequently revised to 15 March]

For tasks 1, 2 and 3, stock assessment documents were received in late January and additional documentation was obtained from SARDI on further request (*see* Appendix 1) and from the published literature. Data from the 2001-02 season were provided by SARDI in July. One of us (PAB) attended a workshop held in Port Lincoln, 15-16 July, and this report was subsequently revised accordingly.

A new draft stock assessment report was provided by SARDI on 14 July 2002. We considered this to be outside the scope of the work for which we tendered, and we do not address the new assessment document in this report.

The scope of task 2, "assessing the status of the fishery" was open to question - it could range from a full stock assessment to an "assessment" of the status based on the analyses provided. The question was clarified by additional information from Roger Edwards to tenderers on 31 December 2001, in response to a query from elsewhere:

> Question - is modelling required?
> Response:
> I cannot answer this question as the approach to part 1 of the review is up to the consultants. However you should be aware that: the task is about reviewing current knowledge and the previous annual stock assessments and making comment about (1) the status of the fishery (2) its future capacity and (3) the "robustness" of previous assessments. As such a full modelling exercise and formal stock assessment is not expected.

A similar approach was taken to task 4, assessment of effective effort increases. Item 3 was addressed mainly through a literature search.

3. Current and Previous Stock Assessments

The depth and variety of data available for stock assessments in the South Australian lobster fishery is impressive (Table 1). Apart from the catch and effort data, for which South Australia has collected very good data compared with many other jurisdictions, most of the data are available only after the early 1990s. A large program funded by industry and FRDC in the mid-1990s (e.g. Prescott *et al.* 1996) was pivotal in obtaining and analysing large volumes of new information on growth, movements, maturity, catch length frequencies, etc.

The major "current and previous" analyses are summarised in Table 2.

3.1 Most recent assessment

The most recent available full assessment was described by Prescott & Xiao (2001), which should be read in conjunction with the update of Prescott (2001a), based on preliminary estimates from the 2000-01 season. The executive summary of Prescott & Xiao (2001) states that:

- estimated recruitment declined from 1998 to 1999,
- catch rates remained high, esp. in the southern NZ,
- pre-recruit abundance declined from 1997-98 to 1999,
- mean weight increased in the same period,
- nominal effort was at a 10-year low, but
- concern was expressed about possible increases in effort.

These conclusions will be examined in some detail to explore the evidence presented.

3.2 Recruitment

Recruitment was estimated using the dynamic qR model, probably the version described by McGarvey & Matthews (2001), which in turn is a refinement of the version described by McGarvey et al. (1997). The qR model is a simple age-structured model fitted to vectors of catch in both numbers and weight, using the effort vector and assuming weights-at-age based on growth estimates (McGarvey et al. 1999). The model's level of biological realism is intermediate between the simple surplus-production model originally used for this fishery and the biologically detailed models now used for other fisheries (e.g. Punt & Kennedy 1997).

Outputs from the qR model are reconstructed biomass, annual recruitment to the fishery in numbers, a single value for catchability (symbolised by q; it is the average effect of a single unit of effort), and exploitation rate (the fraction of the population caught each year). Although Prescott & Xiao (2001) show these results for the Southern Zone for 1999-2000, they do not show the model's estimated recruitment for the Northern Zone, and thus the statement that recruitment declined cannot be evaluated. No statistical analysis has been associated with recruitment estimates, and the issue of significance of the decrease was not addressed.

The authors of the current report fit a similar but not identical model to data that included 2000 (McGarvey, pers. comm.). This model does not calculate exploitation rate from effort, but rather estimates it for each year, and the model is fitted to raw CPUE with lognormal errors using the same CV estimated from the catch data. With this model, the change in estimated recruitment from 1998 to 1999 was small. It is likely that the most recent recruitments are estimated with less precision than earlier recruitment - recruitment for the last year of data affects only part of the biomass for that year, whereas earlier recruitments affect biomass over several years.

4. CPUE

Catch rates were obtained from the logbook data and standardised with general linear modelling (GLM) - the raw and standardised catch rates were very similar. Catch rates were presented for the 6 major NZ MFAs. Data presented support the statement that catch rates remained high in 1999-2000.

For 2000-01 the catch rates declined (Figure 1 of Prescott 2001a and data supplied). Part of the decrease may have been caused by increased minimum legal size (MLS), as discussed in the report. Prescott (2001a) also presents exploratory analyses of swell heights and depths fished, and suggests that the decreased catch rate in 2000-01 cannot be wholly explained by the changed MLS or the pattern of swell.

Prescott (2001a) introduces a new index, based on the frequency of blank pots in each of the major MFAs (no NZ-wide index is given). This shows increases from low values in 1997-98. However, no statistical analysis of these data was presented, and the issue of significance of the increases was not addressed. This approach (looking at components of the distribution of daily CPUE records) could be expanded, as discussed in the Recommendations.

4.1 Pre-recruit indices

Pre-recruit indices (PRI) were obtained from the logbook data and standardised with general linear modelling (GLM). In two other analyses, this index was obtained from a subset of the logbook data and from the voluntary catch sampling data. The index was presented for the whole NZ and for the major NZ MFAs.

The NZ-wide index based on the logbook subset data showed a decline of about 16% from 1998 to 1999 (Figure 6 of Prescott & Xiao 2001 and data supplied). From 1999 to 2000 the index dropped another 14% (Figure 4 of Prescott 2001a and data supplied). However, no statistical analysis of these data was presented, and the issue of significance of the decreases was not addressed. The 2000-01 index remained higher than it had been at any time from 1983-95.

Prescott (2001a; Figure 6) also presents unstandardised pre-recruit catch rates from voluntary catch sampling for each of the major MFAs. No NZ-wide index is presented. These data show strong declines from 1996-97 in MFAs 15 and 28, declines from a peak in 1998 in MFA 39, and slight declines from 1998 peaks in MFA 48.

Two figures show the relation between the standardised pre-recruit and CPUE indices in the same year (Figure 9 upper of Prescott & Xiao 2001), and with a one-year lag (the lower part of Figure 9). Both relations are positive [but the regression model results and high r2 values in the assessment report cannot be reproduced using raw CPUE and PRI from the data supplied for this review] and the correlation is slightly higher with a 1-year lag; with the data supplied the correlation is lower with a 2-year lag and lower still with a 3-year lag.

4.2 Mean weight

Mean weight increased from 1998 to 1999 (Figure 12 of Prescott & Xiao 2001), but the data supplied for the whole NZ show only a small increase from 0.991 to 1.015 kg, or 2.3%. No statistical analysis was presented, and the issue of significance of the increase was not addressed. Mean weights are also compared for the major MFAs. In 2000-01, mean weight increased by 7.5% (Figure 12 of Prescott 2001a and data supplied); part of this increase was probably caused by the increase in MLS.

4.3 Egg production

Egg production was estimated but was not mentioned in the summary for the assessment done by Prescott & Xiao (2001). The values were based on equilibrium egg-per-recruit (EPR) modelling, in turn based on the exploitation rate obtained from the qR model. This was done on an individual area basis, using a “log-link function” to estimate numbers of females in each area. We were unable to determine what this latter procedure was.

Egg production from an equilibrium model will differ from that estimated by a dynamic model (earlier assessments used a the dynamic qR model); in addition, some key assumptions differ between the qR model used to estimate exploitation rate and the equilibrium model used to estimate EPR. Advice on this point was provided to the FMC Scientific Review Sub-committee outside this report.

4.4 Effective effort

Prescott & Xiao (2001) suggest that effective effort might be increasing because of a shift from owner-operator vessels to skipper-operated vessels. Their Table 7 shows that skippers have higher mean days fished, fish more areas and have a higher mean

CPUE than owners. Data in the table suggest that the difference in mean catch per vessel results mainly from the differences in days fished and CPUE, not from differences in mean lifts per day. However, no statistical analysis was presented, and the issue of significance of the differences was not addressed.

Prescott (2001a) examines this question further with a variety of analyses. These are discussed further in the major section below that deals with effective effort. We think the analyses are interesting and ingenious, but that the results are not definitive.

The effects of different levels of increased effective effort on our indicative "assessment results", using our version of the qR model, were supplied to the FMC Scientific Review Sub-Committee outside this report.

4.5 Previous assessments

There has been an evolution in assessments since the mid-1990s. Earlier assessments relied more heavily on equilibrium assumptions and methods, for instance equilibrium EPR and YPR models, length-converted catch curve estimates of mortality rate. Later assessments rely more heavily on modelling, especially with the qR method, and use more of the fishery data (CPUE, catch in weight and numbers, effort).

All the previous assessments (1997-99) were examined, but were more helpful in understanding the methodology leading up to and used in the most recent assessment than in modifying conclusions from the most recent assessment.

4.6 Comments on the assessment

The assessment is a good start, and the qR model appears to be an appropriate tool for assessing exploitation rate and recruitment. The assessment, as far as it goes, gives clear indications of the likely state of the stock, but stops short of being a full assessment: without uncertainty estimates and diagnostic tests (see below) these indications must be viewed cautiously. The sections below discuss these reservations further and recommendations are made for future assessments.

4.7 Relation with management plan

The assessment should be more obviously focussed to address the requirements of the management plan.

The more recent assessments (e.g. Prescott et al. 1999) have had some degree of focus on five key biological indicators listed in the management plan (Zacharin 1997):

- exploitation rate
- catch rate
- egg production
- pre-recruit index
- mean size

The management plan provides the rationale for each of these indicators (it calls them "reference points") and specifies that they will be reviewed at the end of each season as part of the stock assessment process. The plan provides a table of values for the years 1992-93 through 1996-97, and specifies a list of actions for the Fishery Management Committee to take when an indicator value falls "outside the historical range". The implication is that the biomass should

Each assessment should therefore consider explicitly each of the five indicator values in a comparison with their historical range, and to give a clear statement about whether indicators are within or out of range.

Note that the historical range of all indicators except mean weight will be re-estimated with each new assessment. For exploitation rate, as estimated by the qR method: see Figure 16 of Prescott & Xiao (2001), showing the effects of method changes and new data on the estimates. CPUE and pre-recruit indices are re-standardised each time, which changes all values of the index.

4.8 Uncertainty

Realistic uncertainty estimates around results are an integral part of a good assessment (National Research Council, 1998). The current and previous assessments do not present uncertainty estimates in many cases. The statistical uncertainty around estimates should be presented for all quantities of interest and especially the five indicators. For instance, the qR method has outputs in biomass, recruitment, and catchability. The implication of the management plan is that biomass should be maintained near the levels during the historical reference period (an increasingly common approach). Thus the biomass trajectory should be presented with its uncertainty envelope.

Uncertainty envelopes can be sometimes be calculated analytically, estimating by bootstrapping in some situations, estimated from the Hessian matrix, explored in likelihood profiles, or estimated as posterior distributions from Bayesian methods such as Markov chain - Monte Carlo simulation.

As the management plan is written, actions are triggered if values for indicators fall outside the historical range, even by a very small margin. It would be more helpful for the FMC to know whether an indicator was significantly different from historical values in some way. "Significantly different" relates to the probability that results are different from each other by chance observation alone. The FMC should be concerned with: how much natural variation is there in the indicators? and how much observation error is associated with the indicators?

The assessment could present a classical hypothesis test with the null hypothesis that the current value of an indicator is not different from the historical reference; a significant difference would then trigger action.

A good example is mean weight: in 1998 was 0.9912 kg, which was lower than lowest value in the historical range, 1.0034 kg. Was that a significant difference? It seems unlikely to have been, but under the management plan, action would be triggered. Mean weight is based on the whole fishery, not a sample, but nonetheless contains observation error in the number of lobsters landed, and so is an estimate with some observation error.

4.9 Model Diagnostics

The assessment should include consideration of how well the assessment model behaves. We developed our own sense of the qR model by "playing" with our own version with real NZ data. McGarvey & Matthews (2001) provided testing of the model with simulated data, an important step (but limited in this case). Ideally, the assessment should provide diagnostic information, such as:

- plots of the standardised residuals for the data sets fitted
- estimates of standard deviations or median of the standardised residuals for each data set
- sensitivity analyses that explore assumptions made outside the model

- retrospective analyses, in which data are removed one year at a time for several years back from the most recent year

Residuals show how well the model fits the data and show up systematic fitting problems. Sensitivity analyses show how dependent the results are to arbitrary decisions made outside the model. For instance, the rate of natural mortality is assumed to be 10%: how much do the results change when a different value is assumed? How sensitive are the results to the assumption that all lobsters above the MLS are equally vulnerable?

Retrospective analysis shows how sensitive the results are to additional data. If removing a year of data causes a large change in the results, then having an additional year of data is likely to have the same effect, so model predictions from such a model/data combination should be treated very cautiously.

4.10 Risk

When an indicator is triggered, the management plan calls for consideration of changes to the input controls. Stock assessment involves quantitative evaluation of alternative management actions (Hilborn & Walters 1992), including the status quo. It would be useful for the assessment to make short projections, to a maximum of five years ahead, using the current input controls and other controls if so requested. These should be stochastic, based on patterns of variation in recruitment, catchability, etc. seen in the historical estimates.

These projections could be analysed to estimate risks of interest to the industry and managers, such as the risk that biomass or egg production will fall below the historical reference level. Such projections are **essential** when management action is considered. Sample distributions of catches and biomass from 5-year projections from the qR model after the 2001-02 season were shown to the management workshop in mid-July and are not repeated in this report.

4.11 Use of Data

Not all the data are used. Tables 1 and 2 show data sets available and their use. Some data have not been used: for instance, catch rates from the voluntary catch sampling could be used to produce standardised indices analogous to those from the compulsory logbooks, but are not. No recent analysis of larval settlement has been presented, and the relation between settlement and subsequent abundance has not been presented. Data on technological change (Prescott 2001b) were used in a popular article, but have not been applied to the assessment. Ward (pers. comm; see Appendix 2) suggests that some SARDI diver surveys and recreational diver surveys might be useful; no reference is made to these data in the assessment documentation. Temperature data collected by fishers are not used.

Length frequency data have been used only to estimate the effects of MLS change (Prescott & Xiao 2001). McGarvey & Matthews (2001) argue that mean weight captures much of the information contained in length frequency data, but admit that it does not capture all the information. In any case, the qR model doesn't fit to mean weight.

Given the scale of length frequency data available and the measuring effort they represent (in the NZ, about 10 000 fish are measured in this program each year), the assessment should try to use them.

Catch and effort data from before 1970 (Lewis 1981; 1983) are not used. These old data may have important information about historical stock sizes and productivity.

The logbook data are not as straightforward as the existing descriptions imply. See, for instance, the exchange of queries and answers in Appendix 1 concerning the use of these data for obtaining mean weight by MFA by year. Prescott & Xiao (2001, Figure 13) present estimated mean weights from 6 MFAs without discussing how the data were extracted or mentioning that the data are incomplete for some MFAs in some years. A table showing the percentage completeness of the data is required in such a situation.

The same problem, apparently to a lesser extent, may apply to the use of these data for zone-wide annual estimates of catches in weight and numbers. Lack of description of the database and possible errors in the data are issues that require some considerable effort.

4.12 Issues outside the Main Assessment

The current stock assessment documents (from 2001) express concern that effective effort may be increasing, and that the fishery could be expanding in the spatial coverage. Much of Prescott (2001) is directed at exploring the possibility of increased effective effort.

Ideally, such issues should be dealt with inside the main assessment, not in a separate series of analyses outside the assessment. This is especially important when such issues are important and appear to be in conflict with the conclusions of the main assessment. In this case, the main assessment appears to suggest a stable fishery with a moderate exploitation rate; yet management action is apparently being considered on the strength of these other issues.

The assessment should incorporate all the important issues. This point overlaps with "integrated assessment", discussed below.

4.13 Integrated Assessment

The results of the South Australian rock lobster assessment work come from a variety of analyses (Table 2), and in some cases the results of one analysis are used as the input for another analysis. For instance, growth rates are estimated from tagging studies and used to develop the weight-at-age vector required by the qR model (McGarvey *et al.* 1999). Another example is exploitation rate, which is obtained from the qR model and then used in equilibrium EPR analysis (Prescott & Xiao 2001).

This is called "sequential analysis" (Maunder 1999, 2001) and has the disadvantage that different methods involve different assumptions and different error structures; information about the uncertainty of an estimate is lost when the estimate is used in a subsequent analysis. In the EPR example, the qR model estimates exploitation rate from non-equilibrium population calculations, then this exploitation rate is used by a model that assumes equilibrium, and also uses vulnerability-at-length not used by the qR model.

Similarly, the Leslie analysis assumes catchability can vary between years but not between months; the GLM model assumes that catchability can vary among months but not between years, and the qR model assumes an average catchability across all years. Other examples can be found.

The solution is the "integrated model" (Maunder 2001) in which estimates are made simultaneously. For instance, instead of estimating growth parameters from tag/recapture data and using those estimates in a catch-at-age model, the modeller estimates growth simultaneously with the other model parameters, and the signal for growth comes from the other data sets as well as the tag/recapture data. The technology available today makes this comparatively easy.

An ideal model would:

- be spatially structured, addressing the differences among areas
- have a fine spatial scale, addressing seasonal changes

- use all the data

- incorporate all the supposed important aspects of the fishery and biology

- present realistic uncertainty estimates

Ideally, the minimum spatial unit would be an MFA. The minimum time step could be a month. Important aspects of the fishery not now modelled are: seasonal and annual variation in catchability, length-specific vulnerability, differential vulnerability of mature females, etc.

However, it is much easier to write the specifications for the ideal model than to code such a model in a way that gives stable estimates. Despite this, future modelling should begin to evolve toward the ideal. Bayesian models are becoming popular (Punt & Hilborn 1997; Meyer & Millar 1999) partly because they produce easily-understood probability distributions of results, and they allow external information or belief to be incorporated. Good examples of appropriate models to consider as starting points are Hampton & Fournier (2001) and Hobday & Punt (2001).

4.14 Documentation

It is good to see annual or nearly-annual assessment documentation.

Problems that should be addressed, in addition to the issue of addressing the management plan as discussed above, are:

- the assessment methods should be described fully at least the first time they are used, and fully again every few years;

- any changes to methodology should be described fully when they occur, complete with equations;

- the data used should be appended as fully as possible, or put into an accompanying data report;

- all results used in the summary or discussion sections should be shown;

- figures should have comprehensible captions and should themselves be comprehensible;

- truncated axes should be indicated.

Together, the first two recommendations would eliminate the cascade of reference: report A describes results from a method and cites Report B as a reference; Report B doesn't have a description but cites Report C, etc. In this assessment, the qR method was not fully described until McGarvey & Matthews (2001); the "log-link function" used in the EPR model is undescribed, and other examples can be found.

The importance of peer-review in year-to-year assessments, as well as periodic in-depth outside review, was emphasised by the National Research Council (1998). Assessment results should ideally be discussed by all stakeholders and by independent assessment people, ideally at a stage when they can be re-worked and revised if necessary.

5. Assessment of Current State of the Stocks

As discussed above, this is a review of the assessment, not an independent assessment. The goal is to comment on the state of the stock **as it can be assessed from the information provided.**

At the end of the 2000-01 season, the stock appeared reasonably stable compared with other rock lobster stocks and especially with fish stocks with which we are familiar. Catches from the last decade fluctuated between 850 and 1250 tonnes, possibly in response to fluctuating recruitment, as measured by the pre-recruit index. CPUE fluctuated within the range 1.25 to 1.50 in the past decade, excluding the most recent year, which may be affected by the increased MLS. Mean weight in the past 30 years varied (based on the data provided) from 0.95 to 1.13 kg, a very narrow range for such a long period.

Results from the qR model showed that estimated exploitation rate increased steadily through the 1980s but was been in the range 0.28 to 0.32 in the past decade. Recruitment shows fluctuation from 740 000 to 1 700 000 in the last two decades. Surplus production estimates over the past two decades varied with recruitment from 600 to 1200 t and were higher in the last decade than before. Although there is no analysis of length frequencies, the NZ-wide length frequency (Figure 3 of Prescott 2001a) suggests that exploitation rate cannot be high.

Taken together, the observations discussed so far suggested a relatively healthy fishery, although in our draft report we suggested the recent decrease in CPUE bore watching.

Caveats on the observations above included:

- lack of uncertainty estimates
- use of unstandardised CPUE
- exclusion of important data (esp. length frequencies)
- lack of future projections or risk estimates
- simplicity of the qR model (e.g. no vulnerability, a single *q*)
- possible model bias
- apparent changes in dynamics in 1985

Bias in the qR model might come from several sources. We examined some of these, and found as follows:

parameter	estimated rect	estimated U
assumed M too high	**high**	**low**
assumed M too low	**low**	high
older weights too high	-	**high**
older weights too low	-	**low**
early vuln too high	-	**low**
late vuln too high	-	high
q increases with time	-	**low**

If natural mortality rate, M, is over-estimated (i.e. if the real value is less than 10%) then exploitation rate is under-estimated, and conversely (the effect is weaker for under-estimated M). Exploitation rate is also under-estimated if weights-at-age for the older ages are too low, if vulnerability-at-age is too high for the young ages, or catchability (q) increases with time.

To the caveats expressed above must be added the concerns discussed in detail below under "effective effort". We are cautious about these concerns: we can see relatively little hard support for them in the evidence provided. The best evidence would come from an integrated assessment.

Data from the 2001-02 season, provided by SARDI in early July (Appendix 2) changed the appreciation of the state of the stock described above. CPUE delined a further 12 to 13% in 2001-02, reaching a point close to the historical low. The CPUE provided was unstandardised, which is inappropriate because fishing patterns have changed (in particular, some days have been removed from the high-catch rate periods), but properly standardised CPUE would likely have shown a similar trend. Because CPUE is assumed to reflect recruited biomass, the conclusion is that recruited biomass has declined sharply in the past two years and is now near an historical low.

The pre-recruit index also declined sharply in 2001-02. Again, the data are unstandardised, but again the properly standardised data would likely have shown a similar trend. Because of the increased MLS for the 2000-01 season, which should have increased the apparent PRI, this decline is steeper than the raw data suggest. There is a strong relation between the PRI index in the next year (Prescott 2001a); thus these data suggest further declines in CPUE are likely in the 2002-03 season.

Because this work was not an assessment, we did not make projections except to show as examples.

6. Current Knowledge And Implications Of Broader Environmental, Climatic And Oceanographic Influences

The study of oceanic "climate" and its variability on fisheries is functionally a comparatively young one. For lobsters in Australia, the most extensive recent work has been done in Western Australia (e.g. Caputi *et al.* 2001; Griffin *et al.* 2001), but similar studies are also available for the painted lobster (Dennis *et al.* 2001) and for rock lobsters in Florida (Yeung *et al.* 2001), Japan (Inoue & Sekiguchi 2001) and New Zealand (Jeffs *et al.* 2001). Winds have also been implicated in recruitment of pueruli to the shore (Harris *et al.* 1988).

In attempting to understand the changes that are observed in the rock lobster populations and in the fishery in the Northern Zone, the possible broader influence of environmental, climatic or oceanographic factors is of clear interest.

Most effort has gone into attempting to understand factors that may be influencing variations in recruitment to the fishery. This is linked to changes in larval settlement.

Given the observation that settlement/recruitment in the Northern Zone have not been shown to be linked to stock size factors such as egg production, the major contributor to the observed variations in settlement are likely to be "environmental", "climatic" or oceanographic in origin.

In describing the measurement of larval recruitment indices, Prescott et al. (1999) noted at some sites a “possible emerging pattern” of high settlement during La Nina conditions and low settlement during El Nino conditions. This apparent pattern was not well supported by the available data (their Figure 12) and no settlement information for 1999 onward has been reported (e.g. Nothing was mentioned in Prescott & Xiao 2001 about settlement index).

McGarvey and Matthews (2001) established a correlation between August (the time of most post-larval settlement) westerly wind strengths 5 to 7 years earlier and recruitment to the fishery. As they suggest, this indicates an influence on recruitment of longer term mesoscale processes. These include oceanographic features and climate influencing broad scale transport mechanisms that in turn influence late stage larval/puerulus transport across the continental shelf.

As a better time series of larval settlement indices develops and estimation of recruitment is refined, a further exploration of relationships such as this might be warranted.

Relationships between elements of the fishery dynamics and other elements of oceanographic/climate variability have also been noted. Spatial variations in growth rates were in part explained by McGarvey et al. 1999 as density dependent. However, Prescott et al. 1999 also suggested (citing Prescott “unpublished data”) that differences in growth rate are explained by sea temperature. Another important biological parameter – female size at maturity - was also reported to be correlated with growth rates (Prescott et al. 1997).

Prescott (2001a) explored the influence of swell height on catch rates in the Northern Zone and noted that swell energy is thought to reduce catch rates in shallow water and swell height/energy increases. This in part helped explain lower catch rates observed in the NZ in 2000.

Where oceanographic features (such as sea temperatures) and climatic features (wind speed and direction) vary inter-annually, they may also be associated with larger scale events which vary on a time scale of 2 to 10+ years. A measurable influence on the population dynamics and the fishery for Northern Zone rock lobsters might be expected.

Such variables are much more likely to have an impact on population parameters such as recruitment than the level of egg production. Given that egg production is a feature of the management objective which aims to “harvest rock lobster at a size likely to provide for adequate levels of recruitment” and the “total egg production” performance indicator in the 5 year strategic research plan more attention might usefully be directed at the effects of environmental variables on recruitment.

7. Changes in the Level of Effective Effort

The current stock assessment documents (from 2001) express concern that effective effort or fishing power may be increasing because of technological change or altered fisher behaviour. Much of Prescott (2001a) is directed at exploring the possibility of increased effective effort. Increasing effective effort is serious because it distorts the signal from CPUE: the rate of decline in CPUE would be less than the rate of decline in the stock if effective effort were increasing substantially. Assessments that relied strongly on the signal from CPUE would be overly optimistic.

The second issue is raised several times in Prescott (2001a), e.g.:

This difference [seen in Figure 5] *signals the effects of spatial expansion and other attributes of the fishery that contribute to the increase in effective fishing effort.*

One way that fishers have used their gear more effectively is to fish the entire available stock across the 207 000 square kilometres of the northern zone.

Serial depletion would also lead to optimistic assessments, because the CPUE signal would be distorted (staying high as stock declines) and because the length frequency signal is would be distorted (apparent sizes in the catch would be larger than they would be from a fully developed fishery).

A third problem is addressed by Prescott (2001a): the relation between catchability and stock size may not be linear. If catchability increased as biomass decreased, this would lead to “hyperstability” of CPUE: the CPUE would decline less than the biomass declined.

In our view these are separate problems, not related problems, although all three lead to higher than expected CPUE and are potentially serious for the assessment.

The various analyses that explore these concerns are ingenious, but the data are not good and the results are somewhat unsatisfying. A better approach would be to use a model that addressed the issue with the ability to estimate change in catchability.

7.1 Effective effort

Prescott & Xiao (2001) state that "the issue of increasing effective effort is an ongoing and unresolved issue in the rock lobster fishery...." It is a concern common to rock lobster fisheries that changes in technology can increase the fishing power of a pot. For instance, Brown *et al.* (1995) examined the effect of specific technological change on the increased efficiency of pots in the Western Australian fishery for *Panulirus cygnus*. The concern is present in other fisheries, e.g. Robins *et al.* (1998) found that vessels with GPS were 4% more efficient in the same circumstances as vessels without in an Australian prawn fishery.

A questionnaire survey of South Australian fishers gave their estimate of annual 2.7% increases in efficiency in the 1980s (McGarvey & Prescott 1998). These authors suggested that the rate of increase in effective effort in the NZ rock lobster fishery was 2-6% per year in the 1990s, and caused by colour depth sounders, sonar, larger vessels, larger engines, planing hulls, and GPS. Bait is also mentioned by Brown *et al.* (1995).

Prescott & Xiao (2001) and Prescott (2001a) explore the difference in behaviour of fishers, and suggest that changing behaviour leads to increases in fishing power. In particular they describe the higher catch rates and wider ranges fished of "skippers", who fish on behalf of an owner, compared with those of owners.

In the South Australian fishery there appears to be some data on changing technological status (Prescott 2001b), but these has not been used to estimate whether effective effort has increased. If changes in technology are thought to be increasing fishing power, these data should be analysed. The anecdotal view is that vessels and engines have become larger and planing hulls have become more common (McGarvey *et al.* 1997; Prescott & Xiao 2001). The view from a **very** limited sample of fishers is that some major technology changes - colour sounders and GPS especially - had a big effect from 1990-95, but after 1995 were universal and then caused no change. Computerised fishing strategies may be a recent change.

Prescott & Xiao (2001) suggest that effective effort might be increasing because of a shift from owner-operator vessels to skipper-operated vessels. Their Table 7 shows that skippers have higher mean days fished, fish more areas and have and higher mean CPUE than owners. Data in the table suggest that the difference in mean catch per vessel results mainly from the differences in days fished and CPUE, not from differences in mean lifts per day. However, no statistical analysis was presented, and the issue of significance of the differences was not addressed.

The suggestion of Prescott & Xiao (2001) was supported at the meeting on 15 March. Views were that skippers may fish harder than owners because additional profit is required to support the extra link. One view was that information is supplied to skippers in the form of computer files, and advice is only a telephone call away. Thus, under this view, searching time and the effects of inexperience are minimised.

Prescott (2001a) examines this question further with a variety of analyses. In the first, it is demonstrated that traded pots have higher catch rates after the trade. This is suggestive but is not definitive with respect to whether the effective effort is increasing. The results depend on what is happening to the other pots in the fishery.

Next, Leslie analysis is used to estimate annual catchability from the regression of catch rate on accumulated catch, a standard tool. Only the last 12 weeks from each season are used. The annual estimates show an increase from 1991 to 2000 (Figure 16 of Prescott 2001a), despite two MLS changes.

This analysis should be treated very cautiously. An assumption of the method is that catchability remains constant during the season, and that decreased CPUE is caused by decreased abundance. However, in the early part of the season, CPUE does not decline with accumulated catch until the last 12 weeks of the season (Ward, pers. comm.; see Appendix 2). This suggests a seasonal component of catchability, caused by water temperatures or the growth and reproductive events.

Accordingly, it is likely that the decline in CPUE is partly due to decreased abundance and partly due to seasonal change, and of course the two are correlated: accumulated catch increases as the season progresses. So the pre-season biomass estimated by this method will not be correct. Prescott (2001a) suggests that it will be under-estimated, because lobsters do not remain equally catchable during the 12-week period. Similarly, catchability will not be correct. Part of what is measured by the Leslie procedure will reflect catchability and part will be something else, unrelated to catchability.

The exploitation rate implied by the Leslie analysis (Figure 15 of Prescott 2001a) is far higher than that estimated by the qR method: exploitation rate is over-estimated, probably because catchability declines during the season.

It is argued that one can still compare the relative values. That would be true if a) the seasonal change in catchability remained the same every year and b) seasonal fishing patterns were the same in every year. But there is no reason to assume that these have remained constant. Thus, the change in "relative values" seen in Figure 16 of Prescott (2001a) could be caused by something other than changed catchability.

Finally, from the Leslie analysis it would appear that "relative q" decreased from 3 E-7 during 1983-90 to 1.5 E-7 after 1990, a decrease of 50%. If these analyses are taken to reflect changes in effective effort, why did effective effort suddenly decrease in 1991?

7.2 Serial depletion

Serial depletion is more difficult to handle in the assessment, requiring spatially explicit modelling, and is potentially a more serious problem. In the assessments to date there is little attempt to explore the issue. An analysis is made of the frequency distributions of areas fished at different times (Figure 19 of Prescott *et al.* 2001a). The figure appears to smooth the distributions. No analysis is made except that the percent of fishers reporting only one area dropped from 35% in 1983 to 5% in 2000. It is suggested that this analysis reflects expansion of the fishery. However, casual examination of the effort in each MFA over time does not support the idea, and the results in Figure 19 may simply reflect dispersion of fishers over areas already fished rather than expansion of the fishery itself.

Our simple and casual examination of the effort distribution by MFA over the history of the fishery shows little trend over the past decade. We would expect serial depletion to show itself in shifts of effort to the west and into deeper water. In some western MFAs (7, 8 and 10) effort shows an increasing trend, but the percentage of total effort involved is very small. Prescott (2001a; Figure 11) looked at the depth distribution of catches from 1994; this shows no deepward shift. These crude examinations tend to reject serial depletion as a major concern, at least on the scales available for analysis.

7.3 Catchability vs stock size

Prescott (2001a) performed a multiple linear regression on the Leslie analysis results; it is argued that the relative *q* was related to *N1*, the estimated number at the beginning of the analysis each year (i.e., at the start of the last 12 weeks of the season). The relation between these is not shown.

This analysis was discussed above, and must be interpreted very cautiously. *N1* is not estimated accurately, because catchability is not constant during the season. Part of what is measured as *q* by the Leslie procedure will reflect catchability, but part will be something else, unrelated to catchability.

Results of the analysis are used to argue that “as stock size decreases effective effort increases”. But this hasn’t been demonstrated, because the analysis doesn’t estimate stock size and doesn’t estimate effective effort.

Prescott (2001a) also presents an analysis based on with two groups of fishers. “Group “A” fishers are thought to have not changed their fishing practices to the extent of the remaining Group “B” fishers”. They have a lower CPUE than Group B. It is argued that, when catch rates are low, Group B increase their effectiveness, and the difference between the Groups’ catch rates increases. The relation in Figure 18 tends to support this suggestion.

Again, much caution should be used in interpreting the analysis. Results will depend critically on the choice of Group A fishers. This group is very small relative to group B, and how they were chosen is not stated in any detail. Is the fishing by Groups A and B in the same place? This is not stated; if not, we may be seeing area differences in catch rate. The suggested change in relative rates is attributed to Group B increasing their rates. Could, instead, this be attributed to Group A decreasing their rate; i.e. relaxing in poor years and working harder in good years?

There is a widespread belief that catchability increases as stock size declines. This is called the Paloheimo & Dickie (1964) hypothesis, reviewed recently by Francis et al. (2001). They point out that few examples are published that show no relation between *q* and abundance, perhaps because “such ‘negative’ results are often considered unworthy of publication.” They point that among the scarce examples where catchability **increases** with abundance, leading to “hyperdepletion” of CPUE as opposed to “hyperstability”, is the South Australian rock lobster fishery, discussed in a speculative passage in Hilborn & Walters (1992, pp. 190-91).

7.4 Summary

Increasing effective effort, serial depletion and non-linear catchability may be, separately or together, problems in this fishery. However, the evidence provided for them is weak. The strongest evidence for the first and third concerns would be the results of an integrated analysis, one that allowed catchability to be estimated for each year.

8. Summary of Recommendations

8.1 Assessment model

1) SARDI should consider a more biologically realistic model than the qR model. Elements of realism that are probably important and should be addressed include: size-specific selectivity by the fishing gear, seasonal effects on catchability, changes over time in MLS, differential exploitation rates on males and females because of the protection on berried females,

possible systematic changes in catchability, etc. The spatial and temporal scales addressed by the qR model are coarse (the whole Zone, one year) and could be improved in a new model.

2) The main assessment model should address the issues thought to be important but which are now addressed outside the model. Systematic change in effective effort is the most striking example.

3) The model should use an integrated approach. For instance, growth rate parameters should not be estimated outside the model and then treated as data; instead the tag-recapture data could be fitted and growth rates estimated dynamically.

4) The model should include some way of addressing uncertainty in a rigorous way, such as by estimating the posterior distributions of parameters and indicators.

5) If egg production is retained as an indicator, it should be calculated as part of the model dynamics from the estimated female numbers, not from a separate model.

8.2 Use of data

6) The model should use more of the available data. The qR model uses the time series of effort and catches in numbers and weight. This is a small part of the total data set (Table 1). Especially important are the length frequency data, which at present are not used. Other examples include the pre-recruit index, puerulus data, catch rates estimated from the voluntary catch sampling, observations of berried females.

7) Annual data summaries from a season should use a standard format. For instance:

- there are several ways to present CPUE, of which the best would be the canonised year effects from a GLM based on year, month, area, depth and vessel.

- mean weight should be expressed as total weight divided by total numbers.

- length frequencies from the whole fishery should be weighted by the area catches.

8) Many useful analyses could be undertaken outside the model. For instance:

- before results from the integrated model are available, it would be useful to use an equilibrium approach to explore whether exploitation rates from the qR model are consistent with the length frequency data, given the growth rate estimates.

- annual patterns of effort and depths fished could be explored to see if they support the idea of serial depletion in the mid to late 1990s.

- annual distributions of daily CPUE could be explored to see if the form of the distribution has changed as well as the mean.

9) The SARDI rock lobster data base should be properly described, and an effort made to address problems with transcription errors.

10) Some data sets exist that are not properly described. These include recreational diver surveys, lobster observations made by SARDI divers, and technology surveys. These should be worked up.

8.3 Presentation of results

11) The assessment report should be independently peer-reviewed.

12) Assessment methods should be described fully at least the first time they are used, and fully again every few years, to make the documents less "updates" and more "stand-alone".

13) The data used for an assessment should either be appended as fully as possible or put into an accompanying data report

14) The assessment report should explicitly address the indicators listed in the management plan.

15) The assessment report should show diagnostics from the assessment model. These should include bias testing with simulated data, fits to the data, residuals from those fits, analysis of the distributions of residuals, sensitivity analyses, retrospective analyses.

16) The assessment report should, especially if management action is contemplated by the FMC, present stochastic forward projections with a realistic treatment of recruitment. Five-year projections are the longest that should be contemplated. Risk analyses should then be presented.

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11. Glossary

This glossary was requested by the Northern Zone FMC. It is aimed at a non-technical audience, so no definition should be considered technically defensible.

accuracy: described under "precision" below, but they are not the same thing.

age-structured model: a model that keeps track of fish by age and year. The number of fish aged 4 in 1999 will be related to the number of fish aged 3 in 1998, and so on. The alternatives are length-based models, and models without age or size that simply have one number for fish or fish weight for each year.

axes: on a graph, the horizontal direction is called the x-axis and the vertical direction the y-axis; together they are the "axes", pronounced ax-ees. Similarly, one index two indices.

bias: when a measuring or estimating procedure tends to have error (inaccuracy) on one side of the true value, that is bias.

biomass: the weight of fish out there in the water. Usually reported in **recruited biomass**, which is the weight of fish above the minimum legal size, and hence could be caught. A **biomass trajectory** is just a series (a vector) of biomass estimates, e.g. from 1978 to 2000. Usual symbol is *B*.

catch rate or **CPUE:** catch per unit of effort, thus catch over a period (a day, a year) divided by the number of units of effort (pot-lifts), to obtain catch per pot-lift. Can be calculated by numbers or by weight. Considered an index of the abundance of fish, when averaged appropriately. **Standardised catch rate** or **CPUE** is calculated with a statistical procedure (such as one called General Linear Modelling) that might use the month, the statistical area, the vessel and the year. The idea is to remove the effects of different months, areas and years from each day's CPUE, and to estimate the real differences among years. Usual symbol is *I*.

catchability: the effect that one unit of effort has on the whole stock, thus is a very small number. Allows the biomass to be related to CPUE. Usual symbol is *q*.

correlation: measures how much two values (e.g. annual temperature and annual rainfall) rise and fall together (a positive correlation) or how much one rises when the other falls (a negative correlation). The important result is the "r^2" or "r-squared" value, which can range from zero (no relation) to 1 (a perfect relation) and describes how much of the joint variation in the two data sets is "explained" by the correlation.

CV: abbreviation for "coefficient of variation", as used here it is a statistical measure of the uncertainty of data, and is used in the fitting procedure.

effective effort: first, "effort" is defined as some measurable unit of fishing that produces catch. In lobster fisheries, a "pot-lift" is convenient to use, even though different lifts may differ a lot in effectiveness because of differing soak times, bait, weather conditions, season, etc. Note that steaming, cutting bait, cleaning the deck, etc. are work but don't come into the "effort" measure. **Nominal effort** is simply the number of units reported on compulsory logbooks. **Effective effort** incorporates the relative change in effectiveness caused by factors such as technology or experience. If GPS makes you twice as effective as in 1985, then 100 pots today are fishing as 200 pots were in 1985.

equilibrium egg-per-recruit: or equilibrium **EPR**: imagine 1000 females of age 3. At this age maybe they are all immature and produce no eggs. At age 4, there might be 900 females, because 100 died, 100 are mature and each produces 2000 eggs. So 200 thousand eggs. At each age a biologist can model the number left alive (by assuming mortality rates), their maturity from biological data, and the numbers of eggs produced for each age from biological data. The total eggs produced (the sum over all ages) is the number of eggs produced by the 1000 females during their lifetime, in a population with the assumed mortality rates, hence "at equilibrium" with recruitment of 1000 females and those mortality rates.

YPR stands for yield-per-recruit, and is calculated in a similar way, but represents yield to the fishery available under equilibrium conditions.

The opposite concept is "**dynamic**", where there is no assumption that anything is in equilibrium. The qR model allows fishing mortality and recruitment to vary each year, so the egg production from that is a dynamic rather than equilibrium estimate.

exploitation rate: the fraction of the population caught by fishing in a particular year. If the biomass is 2 million kg, or 2000 t at the beginning of the year, and the catch is 1 million kg or 1000 t, the exploitation rate that year was 50%. Usual symbol is *U*.

fit, fitting: models are “fitted” to data as follows: the model equations make predictions of the data (thus the qR model makes predictions of catch in numbers and in weight), there is some procedure for comparing the model predictions with the real data (e.g. a likelihood equation), and there is some procedure (called a minimiser) for changing the model (e.g. its values for recruitment) so that it fits the data well.

hyperstability: for CPUE to be a good index of abundance, there should be a directly proportional relation between CPUE and abundance. If there is a different relation, hyperstability means that CPUE tends to stay high while biomass declines. The opposite is **hyperdepletion**, which means that CPUE declines faster than biomass falls.

indicator: one could measure many things about a fishery, and many more from model results. An indicator is just something managers and industry agree should be tracked. This fishery uses mean weight, CPUE, pre-recruit index, estimate egg production and exploitation rate as indicators. This choice is mostly arbitrary.

length frequency: the number or percentage of lobsters in each of a number of size groups; shows the pattern of size in the population.

Leslie analysis: a plot of CPUE against cumulative catch during the season. One expects to see a declining line, and the extrapolated point where CPUE is zero is taken as the pre-fishery biomass. Involves some assumptions that are critical.

maturity: usually used for females only, and refers to the ability to produce eggs.

mean weight: as used in the South Australia, the total weight lobsters caught (for some area) divided by the total number of lobsters caught in the same area, both weight and numbers coming from one whole year of fishing.

observation error: you stand on your bathroom scales and read 84 kg. If you really weigh 88 kg, this is observation error of 4 kg, which could be caused by bias and imprecision in the scales or by you mis-reading the scales. Similar idea applies to CPUE.

peer-review: critical reading of, and comment on, a draft publication by independent scientists.

pre-recruits: fish smaller than the minimum legal size (MLS).

precision: this term is used to refer to estimates or measurements. A precise measurement can be replicated. For instance, you step on the scales and they say you are 87 kg, you step off and back on and now they say 84 kg. Not precise. **Accuracy** is a different concept. Suppose the scales say you weigh 86.5 kg, and they say this four times in a row. Good precision! But if you really weigh 88 kg, however, they're inaccurate.

projections: models are fitted to the data available. The model can be run forward, past the most recent data, using specified fishery conditions such as effort or catch. The results are called "projections" to distinguish them from the results that were fitted to data.

puerulus, pueruli: the newly-settled stage of rock lobsters; -us is singular and -i is plural.

recruitment: the strict definition is the addition of new individuals to the stock by reproduction and growth. So recruitment happens when lobsters grow from sub-legal to legal size, or migrate into the stock from outside. More loosely used to refer to addition of new individuals to the population, for instance by larval settlement. In modelling can be used to mean recruitment to the first cohort of animals in the model.

reference level: something to compare indicators to - for instance, CPUE is an indicator, but what should we compare it to? The answer is a reference level.

regression: a statistical procedure. In its simplest form, it describes the mathematical relation between two variables. For instance, for a lobster of a certain length there is an expected weight, and SARDI has worked out a formula based on a lot of length-weight data and a regression analysis. Can involve more than two variables, e.g. multiple linear regression is used to standardise CPUE.

residuals: when comparing model results with real data, the residual is the difference between each pair of data points.

serial depletion: caused by a fishery that depletes a previously unfished area and then moves on to the next one.

significance: a statistical term that relates to how likely it is two estimates are really different. In reality, this is calculated as how **unlikely** it is that the difference between two estimates could have been obtained by chance when the true value was the same. A **significant** difference is one that is unlikely to have arisen by chance.

simulated data: generated mathematically on a computer to look like real data but with known specified properties. Carl Walters calls it fake data. Nothing dishonest here; the use of this kind of data is important to test models.

stock assessment: involves the use of “statistical and mathematical calculations, along with fishery and biological data, to make quantitative predictions about the reactions of animal populations to alternative management choices” (Hilborn & Walters 1992). Important elements are: **quantitative** results, use of **data** (other wise this is just a simulation modelling exercise), **statistical fitting** of the model to data, **alternative** management choices. Hilborn & Walters is a good reference.

vector: a series of related numbers, such as the string of annual catches from 1978 to 2000, or the number of lobsters in 1998 that are of age 1, 2, ... 13 years old.

vulnerability: in theory, a lobster above the MLS can be caught. However, some lobsters may not be caught at the same rate as others, because females cannot be kept while berried and smaller lobsters are less likely to get caught than larger ones. This effect can be quantified and is called reduced vulnerability.

Table 1. Data available for rock lobster stock assessments, their source and most recent reference, and the uses to which these data been put. Abbreviations: CELRs: compulsory catch and effort landing return forms; GLM: general linear model, EPR: egg-per-recruit; YPY: yield-per-recruit.

data	source	most recent reference	used in
catch in number	CERLs	Prescott & Xiao 2001	qR model, GLMs, descriptions
catch in weight	CERLs	Prescott & Xiao 2001	qR model, GLMs, Leslie, descriptions
effort in lifts and days	CERLs	Prescott & Xiao 2001	qR model, GLMs, Leslie, descriptions
pre-recruits	CERLs	Prescott & Xiao 2001	GLMs, descriptions
dead	CERLs	Prescott & Xiao 2001	descriptions
ovigerous	CERLs	Prescott & Xiao 2001	EPR model, descriptions
bycatch	CERLs	Prescott & Xiao 2001	descriptions
catch rate in weight per pot	voluntary sampling	Prescott & Xiao 2001	
catch rate in number per pot	voluntary sampling	Prescott & Xiao 2001	
catch rate of pre-recruits per pot	voluntary sampling	Prescott & Xiao 2001	GLMs, descriptions, comparison with qr model output
length frequency of catch	voluntary sampling	Prescott & Xiao 2002	effect of MLS change
larval settlement	collectors	Prescott *et al.* 1999	descriptions
growth rates	tag returns in FRDC study	McGarvey *et al.* 1999	qR model, EPR and YPR models
movement	tag returns in FRDC study	Prescott *et al.* 1996	descriptions
fecundity-at-length	Tasmania	Kennedy	EPR model and qR model
maturity-at-length	setae in FRDC study	Prescott *et al.* 1996	EPR model and qR model
vulnerability-at-length		Prescott *et al.* 1996	EPR and YPR models
weight-at-length	FRDC and other studies	McGarvey *et al.* 1999	qR and YPR models
vessel characteristics	questionnaire 1991	McGarvey *et al.* 1999	descriptions
vessel characteristics	???	Prescott 2001b	descriptions
pot characteristics		Prescott 2001a	descriptions
fisher catch rates	CERLs	Prescott 2001a	estimates of increased efficiency
sea surface and bottom temperature	voluntary sampling	Prescott *et al.* 1996	descriptions
diver surveys	???	Ward (pers. comm)	
swell data	no reference	Prescott 2001a	descriptions

Table 2. Major analyses report in recent assessments, the data they use and their outputs.

Analyses	Using	Most recent reference	Output
qR model	catches in numbers and weight, effort, weights-at-age	McGarvey et al. 1997	exploitation rate, biomass, recruitment, catchability, egg production
Walters-McGarvey model	many kinds	McGarvey& Gaertner 1997	projected catch, biomass, exploitation rate, CPUE (not an assessment model)
EPR model	exploitation rate, vulnerability, maturity, fecundity-at-length	Prescott et al. 1999	equilibrium EPR effects of MLS change
YPR model	exploitation rate, weight-at-age, vulnerability, maturity,	Prescott et al. 1996	equilibrium YPR effects of MLS change
GLM	catch and effort	Prescott & Xiao 2001	standardised CPUE
GLM	pre-recruits, effort	Prescott & Xiao 2001	standardised pre-recruit index
GLM	catch sampling	Prescott & Xiao 2001	C/S pre-recruit index
Leslie	CPUE, catch	Prescott 2001a	estimated catchability, change over time
ad hoc	CPUE	Prescott 2001a	change in effort effectiveness
GROTAG	tag returns	McGarvey et al. 1999	growth rates
moult timing	tag returns	Prescott et al. 1996	estimates of moult cycles
length-based mortality	growth rates and LFs	Prescott et al. 1996	total mortality estimates
U from tagging	tag return rates	Prescott et al. 1996	exploitation rates

Appendices

Appendix 1: Queries and Answers

(Answers and notes are in italics at the end of each query)
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15 February 2002

Dr Tim Ward
by email: Ward.Tim@saugov.sa.gov.au

Tim:

I've been working through the assessment documentation and am at the point where I have a fair number of queries. I direct these at you as the best person to decide who should answer them.

The queries arise from various kinds of issue: I am unable to understand something, which might be my own shortcoming; information seems to be missing; procedures chosen could be debated. In what follows I just fire away with the queries - at this stage, no criticism of the assessments should be inferred. Before I write the draft report I will be conferring to ensure that my comments are at least consistent with the facts.

More questions will undoubtedly follow.

I am copying this list of queries to Roger and PIRSA so that everything is transparent, or alternatively is visible, depending on how you use that jargon.

Thanks in advance.

Paul A. Breen
Scientist

Query 1. I'm interested in the assessment process. Were the analyses in Prescott (2001) and Prescott & Xiao (2001) discussed by, or guided by, any sort of working group? Did the group comprise other stock assessment scientists? industry representatives? independent consultants? Similarly, were the results of analysis discussed by such a group? Were these two reports peer-reviewed within or outside SARDI before publication? *answered by reading the management plan's description of the FMC process and in phone conversation with Tim Ward on 26 February*

Query 2. The latest full assessment is that of Prescott and Xiao (2001). They rely in part on results of the dynamic qR model (e.g. page 6 first sentence and page 37 et seq.) However, they do not present figures for the recruitment results from the qR model, or those for qR biomass, although they do present such results for the southern zone and for the northern zone in earlier documents. If possible I would like to see these results, preferably as numbers rather than in a figure. *not answered*

It would also be helpful, if possible, to see the actual data used by the qR model for the 2000 assessment: for the NZ as a whole, the catches in numbers and weight, and effort in lifts. *answered in email from Rick McGarvey on 19 February*

Finally on this point, it would be helpful to see a description of the changes made to the qR model after the last description, which was made by McGarvey et al. (1997). Since then, the model has been altered by using pot-lifts as an input (McGarvey et al. 1998 page 5), other changes (op. cit. page 6) and still further changes (Prescott & Xiao 2001 page 37). *the reference is McGarvey & Matthews (2001)*

Query 3. With reference to Prescott & Xiao (2001):

3.1: The fourth paragraph on page 6 suggests that the change in legal size will increase male YPR - results are not shown in the report - what model was used? *see Prescott et al. (1996)*

3.2: Figure 4 - what are the x and y axes for each little plot, and what does each symbol represent? *not answered*

3.3: Appendix 1 is not clear - what does “licence condition” mean? Are these seven different alternative options? So, for instance, 15 guys opted for “168”; they all took 9-22 March off and each took another 11 days off when they chose? Presumably a day off is a day with pots out of the water, is that correct? *answered in phone conversation with Tim Ward on 26 February*

3.4: page 29 - was a single NZ index of pre-recruit abundance calculated from catch sampling that could be compared with the one from logbooks in Figure 6? *phone conversation with Tim Ward on 26 February: no*

3.5: Figure 9. The population structure in the NZ is heavily composed of large fish (Figure 3 in Prescott 2001), and the vulnerability of fish just above the MLS is not 100% (page 20). Thus, a very large pre-recruit cohort should not have an immediate effect on the fishery, and the effect would be buffered. In turn, this suggests that the correlation seen in Figure 9 between pre-recruit and recruited catch rates in the same year arises from an external influence on catch rates, affecting both components in the same way. Is that reasonable? Similarly, the correlation in the lower panel may arise from autocorrelation in whatever the external factor is - is that reasonable? *phone conversation with Tim Ward on 26 February: we agreed to drop this as a query*

3.6: page 32: the catch sampling is used to estimate pre-recruit catch rates; is it not used to estimate recruited catch rates? If not, why not? *phone conversation with Tim Ward on 26 February: sample size thought to be too small*

3.7: page 36: it is hard to see where seasons start and end in the figure: am I right in thinking that the proportion of catch taken per month is high at the beginning of each season, and drops to very low levels in the last couple of months? and that mean weight increases steadily during the season? So in Figure 13 of the November 2001 document, the seasons can be distinguished because they end on the highest mean weight? During the season, is there a pattern in the depth fished? - I cannot distinguish the season boundaries in Figure 3 of this document. *phone conversation with Tim Ward on 26 February: yes, yes, yes, and yes - see analysis of depth by season in the reports*

3.8: page 36 and Figure 15 refer to series of mean weight estimates “weighted by the pattern of catches during the 1983 season”. What was done? *phone conversation with Tim Ward on 26 February: I didn’t understand the answer; not important enough not to pursue.*

3.9: page 41: I’m curious about the “log-link function” used to calculate numbers of females from a GLM. The reference is to Prescott et al. (1999), but those authors simply say that relative lobster abundance was “calculated by use of a log-link function” in a GLM. *written answer 27 February:*

> *It is not clear, Yong agrees. What was done was to extract an area-specific trend by use of a generalized linear model (assuming errors in the catch follow log-normal, -gamma, Poisson, or –negative binomial distribution) and use it as weights to weigh up the egg productions. It was put somewhere in previous assessment reports (Prescott et al. 1999, p.13) [that’s where the reference is that I queried...]*

Query 4. With specific reference to Prescott 2001.

4.1: paragraph beneath Figure 4, referring to Figure 5: The text makes reference to the periods 1990-92 and 98-99, but the figure axis is in consecutive months. Is the 1990-92 period months 50-70? and the period 98-99 months 106-119? In this paragraph, the point seems to be that pre-recruit catches in 1990-92 were much lower than recruit catches, but in 1998-99 were the same as recruit catches, is that correct? How does this "signal the effects of spatial expansion and other attributes.....”). *phone conversation with Tim Ward on 26 February: yes and yes; last query not answered*

4.2: Figure 7: what data were used as the basis for the straight line? Is the straight line a predictive regression? I have trouble reconciling this figure with Figure 9 of the previous year's report. *phone conversation with Tim Ward on 26 February: yes, a regression; points are from 97-2001 whereas previous graph shows earlier data also*

4.3: Table 4 is unclear. What are the units in the table? What are the rows in the table? Is the table based on comparing the catch rate of pots before they were transferred with the mean catch rate, and assuming that the pots change to the mean rate after transfer? If so, why not compare the **actual** before and after rates? *phone conversation with Tim Ward on 26 February: each unit is the fraction of a licence; each row is one transfer, yes, apparently cannot be done*

4.4: Figure 14 is also unclear. It isn't clear what each symbol represents. I've tried to understand the caption, but I'm not smart enough. Is there a way to explain this plot? *phone conversation with Tim Ward on 26 February: unable to explain, query dropped*

4.5: on the same issue: Is it possible, more simply, just to multiply the vessel effect from CPUE standardisation by the number of pots for each vessel, for each year, to obtain an effective effort measure? *phone conversation with Tim Ward on 26 February: apparently cannot be done*

4.6: The Leslie model: why were only the last 12 weeks of the season used? It appears that catchability decreases in the late season, resulting in an over-estimate of q. Does this make the comparison among years sensitive to anything that changes the seasonal pattern of catchability? For instance, if fishers caught their fish sooner in the season, then the apparent catchability would be greater, is that correct? *phone conversation with Tim Ward on 26 February: no decline in CPUE before the last 12 weeks; yes some sensitivity; see Prescott's argument that comparison among years is valid*

4.7: the paragraph below Figure 16 states: "as stock size declines effective effort increases". The basis is that the N1 values obtained from the Leslie analysis declined over time - is that correct? Is there a relation between the N1 values and the real stock size? - the N1 values apply only to the period 12 weeks before the season end. *not answered*

4.8: the section beginning two paragraphs after Table 5: it appears that Group A fishers were chosen because they did not change their fishing practices as much as was thought to happen in the remaining fleet. Group A had lower CPUE both in 1983 and in 2000 (and thus were somehow unrepresentative even in 1983?). The argument is that the difference between Group A and Group B CPUE increased over time - is that correct? Could that be tested? *phone conversation with Tim Ward on 26 February: no, the main point is that Group B fishers increase their effectiveness at low stock sizes*

Then Figure 18 shows the ratio of catch rates plotted against Group A rate, suggesting a relation. I don't understand the relevance of this plot to the idea that *q* increases as stock decreases. *see above*

4.9: Under Figure 18, the paragraph discusses possible spatial expansion in the fishery. Page 18 of Prescott et al. (1999) also describes the spatial expansion of the northern zone fishery, referring to a non-existent section. What is the evidence for spatial expansion of the northern zone fishery? Are the annual landings-by-MFA available? *phone conversation with Tim Ward on 26 February: belief that some areas are now heavily fished whereas before they were not [see subsequent query]*

Query 5. With specific reference to Prescott et al. (1999):

5.1: page 12. The EPR procedure described here differs from the one used in 1997 (McGarvey et al. 1997). Why is the equilibrium procedure used to estimate egg production index instead of the qR method, as was used in 1997? Is the equilibrium procedure documented anywhere (i.e. equations provided)? *phone conversation with Tim Ward on 26 February: the equilibrium EPR was thought to be more appropriate, described in Prescott et al. (1966). written answer 27 February:*

> *It differs from the previous egg production procedure. It is not an equilibrium procedure in the sense that the weights depend on time and a lot of other factors. In other words, it was used as an interim measure to deal with the complex picture that is characteristic of egg production. Jim asked for it and he got it. The procedure is not published (to simple to), but is documented on page 13*

5.2: page 18, discussing the knife-edged selection of the qR method: was the sensitivity of the method to vulnerability/selectivity ever tested? *phone conversation with Tim Ward on 26 February: no*

Query 6. A questionnaire survey was used in 1991 to look at vessel characteristics and to get the fishers' estimates of gear efficiency increase. In this set of documents are several references to efficiency increases resulting from vessel changes: vessels are more powerful, tend to have planing rather than displacement hulls, etc. (e.g. Prescott & Xiao 2001 page 14; McGarvey et al. 1997, page 3) Are these data collected and if so have they been analysed? *phone conversation with Tim Ward on 26 February: a study was planned but not done. [see more below]*

Query 7. What is the current voluntary catch sampling design: how many fishers, how many pots, what time scale? *phone conversation with Tim Ward on 26 February: 74 fishers sampling 1 to several pots per day. [later] the 74 catch samplers relates to both fisheries. In the NZ there are 37*

Query 8. Prescott et al. (1999) suggest on page 17s and 19 that an age- or length-based model should be developed, and I thought I saw (but can't find) a reference to a model being developed. Can I please obtain an overview of this model: what data will it use, what parameters will it estimate, what structure will it have, etc? *written answer 27 February:*

> *An age- (or equivalently length)-based model is being developed. It will use logbook data, length frequency data, and other sources of biological data. Recruitment parameters and two others will be estimated. The basic structure is outline in Xiao (2000, Ecological Modelling 128:165-180), with stochasticity being spread all over the place*

From:	Paul Breen <p.breen@niwa.cri.nz>
To:	ward.Tim@saugov.sa.gov.au
Subject:	request for data
Date sent:	Thu, 21 Feb 2002 10:49:47 +1300

Tim:

Hi. First, please note that the middle and third parts of my second query, from the list sent on the 15th, have been answered by Rick McGarvey.

I would like to obtain, if possible, the following two sets of data. This request is associated with tasks 1a and 2 of Objective 1 of the terms of reference of our contract. However, I am very sensitive to the fact that extracting and collating the data might be quite a lot of work that nobody is available to do on short notice. Please therefore feel free to tell me so; the data would be helpful in preparing the review but they are not essential; if they cannot be provided on short notice then that will not be a problem.

1. This is an expansion of my query 4.9 from the previous list. I would like to look at the effort and catch (in numbers and weight if possible) for all NZ MFAs from 1990 to the present, preferably in spreadsheet form. *answered in spreadsheet sent 28 February (see subsequent exchanges)*

2. In Prescott et al. 1996 (the final report to FRDC) there are figures showing the length frequency data from MFAs 15, 28, 39, 40 and 48/49 through 1995-96. I would like to look at the comparable length frequencies for 1996-97, 98-99, 99-00. *answered with a spreadsheet supplied on 5 March*

Thanks in advance.
Cheers
Paul

From: Paul Breen <p.breen@niwa.cri.nz>
Subject: RE: data query
Date sent: Thu, 28 Feb 2002 13:49:22 +1300

Tim:

Thanks for the catch and effort data by MFA and in advance for the reprint.

I have a query about the data you sent. Rick earlier sent me vectors of annual catches and effort for the NZ as a whole, for me to use in examining the operation of the qR model.

Simple pivot table extractions of total NZ catches and effort by year from your data set show is reasonably good agreement with the data Rick sent - see the spreadsheet attached. However, the catches in numbers are substantially higher in Rick's data set for the period 1970-74, and 4-8% higher for 1975-76.

This causes the mean weight for 1970-76 to be smaller in Rick's data set than the mean calculated from your data set - these are plotted on the spreadsheet. Using your data causes significant change to the qR model results for the early years compared with
results from Rick's data.

My query, call it 10.1, is: why are the estimates of catch in numbers different between these two data sets for the early years?
written answer 4 March:

> *Please find attached the version of the mean weight data that you should use for your analysis. Note that there are differences between these data and those used by Rick. Have spoken to Rick about these and he agrees that the current data are those that we should use. Note that data Rick used previously had problems resulting from missing values (i.e. weights without numbers and vice versa)*

From: Paul Breen <p.breen@niwa.cri.nz>
Subject: RE: data query
Date sent: Mon, 4 Mar 2002 12:22:13 +1300

Tim:

Thanks for the new data set.

I am still not clear about what was done in putting together catch and effort data sets for use by the qR model.

The time scales of data over which the qR model was used vary from 1983 onwards (in the original description of the steady-state model and early stock assessments) to 1978 onwards (in the primary description of the dynamic model and in Prescott & Xiao 2001) to 1970 onwards (in the 1999 assessment and for the SZ in Prescott & Xiao 2001).

From the data you and Rick have provided, it appears that data reporting was pretty complete from 1983 onwards. Before 1983, some records lacked weights, numbers, or both.

The qR model uses catch in numbers and catch in weight, Cn and Cw respectively. Among the data sets I now have [please note that I don't want any more], it appears that Cn and Cw were greatly under-reported until 1983. Evidently some procedure was used to estimate total Cn and Cw for the years with data missing (see the comparisons in the spreadsheet attached). For the analyses that began in 1970 this procedure becomes important. It could also be important for the analyses that began in 1978.

My queries are:

11.1: for the period 1970-83, how were Cn and Cw estimated from the data available? I think equations are necessary, because there is a variety of possibilities. *see below*

11.2: is the procedure used to estimate Cn and Cw described in any of the stock documents I have? *see below*

11.3: is there opportunity for the procedure used to have biased the estimates of Cn and Cw? *see below*

11.4: are records with missing effort data numerous enough in any period to be important? If so, how was effort estimated? *see below*

Thanks again in advance
Paul

From: *"Ward, Tim (PIRSA - SARDI)" <Ward.Tim@saugov.sa.gov.au>*
Subject: *RE: data query*
Date sent: *Mon, 4 Mar 2002 11:32:43 +1030*

Paul,

I think that you should cease to use the data that you call TW1. There was clearly an error with that query. (Note that Cn in TW1 for years up to 1975 are clearly lower than those in TW2, so that the issue of missing values alone does not explain the discrepancy.)

As explained in the note on the spreadsheet containing TW2 those data should be used for estimating mean weight only. Those data should not be used as estimates of the total catch.

The total weights and numbers by season are considered to be correct and were used directly in the qR model. The problem with missing values comes about when we estimate Cw and Cn at some higher resolution (eg mfa). Not all data are available for each cell. Monthly data (combined by mfa - i.e. Rick's data) are considered to be OK.

No equations were used to estimate Cn and Cw.

Hope this helps.
Regards.
Tim

From: Paul Breen <p.breen@niwa.cri.nz>
Subject: RE: data query
Date sent: Mon, 4 Mar 2002 17:04:40 +1300

Tim:

When you say "the total weights and numbers by season are considered to be correct", I don't understand where those are obtained. *see below*

The description of the logbook data (e.g. Prescott & Xiao 2001) has the fishers filling out forms with date, MFA, effort, number, weight, etc. So I have been assuming that you have a database with these records and you can do some kind of an extract to get the total catches and effort by year. You appear to have been doing extracts from a database to answer these queries.

In your previous email you led me to believe that there were records with missing weights or numbers, and this prevented you from having complete catches by MFA by year. If there are records with missing weights or numbers, how can you have "total weights and numbers by season" that are complete? *see below*

In other words how, from your database, do you obtain the yearly total catches by year in weight and number? *see below*

Thanks in advance,
Paul

From: "Ward, Tim (PIRSA - SARDI)" <Ward.Tim@saugov.sa.gov.au>
Subject: RE: data query
Date sent: Mon, 4 Mar 2002 15:14:00 +1030

Paul,

I can't be explaining this very well. I will try to explain it another way.

Not all numbers and/or weight entries have mfa information. Therefore, when data are extracted BY MFA (cf for all mfas) there are discrepancies between the total numbers/weight for each season.

ONE of the reasons that there are not mfa data for each record is that fishers sometimes fish for several days and keep their fish in live holding tanks. On these occasions, the total number and weight of fish taken is only be determined after several days fishing (during which they could have fished in several areas). On these occasions total numbers, weight and effort data for those fishing days are recorded together and (obviously) there are no data by MFA.

There are other scenarios. Sometimes weights OR numbers (i.e. not both) of fish caught are recorded each day, but the totals of both are only recorded for all fishing days combined. This creates irregular gaps in the database but totals provided in Rick's spreadsheets remain correct.

Bottom line is:
(1) You need to use the data in TW1 for mean weight estimates.
(2) You need to use numbers and weight data from Rick's spreadsheets for total catch and effort.

Hope that this resolves your query?
Thanks for your patience.
Tim

From: Paul Breen [mailto:p.breen@niwa.cri.nz]
Sent: Tuesday, 5 March 2002 8:44 AM
Subject: RE: data queries

Tim:

Thanks for your note about the catch database and for the length frequency data.
On the latter I have a query:

12.1 In the length class column, about 1000 fish show up in length class "995 to 999.9" Is this a coded group of some sort? If so, what does it mean? If not, is it a mistake for "95 to 99.9", or what? *written answer 5 March:*

Yes the length class 995 to 999.9 is a coded group for fish with unreliable size estimates

On the former I am beginning to appreciate that your database is rather more complicated than I imagined. Just let me check this once more: *written answer 5 March:*

The database is very complex and contains research as well as C & E information

12.2 Every final landing record has effort, and it has catch in both weights and numbers recorded, is that right? In no case does a landing record have catch in weight only, or catch in numbers only, or catches but no effort. Is that right? *written answer 5 March:*

That is the intention, and as far as I am aware all cases have catch in weight and effort data. However, I suspect there are a small number of records without numbers data. I will get back to you with the precise number of records in this category

12.3 Are consistency checks made to see whether the mean weight for a landing is reasonable, or whether the CPUE is reasonable? [In New Zealand the Ministry has a landing record in their database where a guy caught close to a million kilos one day from 50 or 60 pots.] *written answer 5 March:*

Yes, most gross errors have probably been picked up but no doubt some errors remain

12.4 Is this database fully described anywhere? *written answer 5 March:*

Not yet, it has been continuously updated over the last few years

Thanks again.
Cheers
Paul

From: Paul Breen <p.breen@niwa.cri.nz>
To: ward.Tim@saugov.sa.gov.au
Subject: more queries
Date sent: Tue, 2 Apr 2002 16:21:53 +1200

Tim:

Can I get some more info please:

13. To conduct the work requested by the sub-committee, I need the appropriate vector of eggs-at-age for the Northern Zone. This is referred to on page 7 of McGarvey et al. 1997. *written answer 4 April:*
Here are the twenty values we use for ages 1 to 20, where age=1 means the first year of fishable size:
fecNZ={114491, 187553, 236762, 269339, 291286, 306221, 316424, 323399, 328169, 331430, 333658, 335180, 336219, 336928, 337413, 337744, 337969, 338123, 338228, 338300}.

This vector includes both maturity and fecundity. Specifically:

(1) Von Bert params a = 100 ,b = 120, ga = 10.5, gb = 4.15.
(2) Initial length of age 1 females, L0 = 106.86
(3) David's (and my) maturity-at-length logistic params, cmat=0.124 & L50mat = 102.7
(4) Bob Kennnedy's fecundity-at-length vector: fecundit y= (0.226 len^2.912)*

14. I would like to know more about the data described by Prescott 2001b. Could these data be analysed to estimate the effect of these technological changes? *written answer 4 April:*

Data in Prescott (2001) and additional information are being used in the analysis of technological changes in both zones that Yong is undertaking now and that will be presented to industry in July

15. Is the westerly wind index described by McGarvey & Matthews (2001) calculated routinely each year? If so, what are the values for the years following those reported by McGarvey & Matthews? *written answer 4 April:*

No the western wind time series has not been updated. Jim never actually presented the results of this western wind correlation with recruitment to the NZ fishers or FMC as far as I understood. So that hadn't previously entered into discussions in a management context

16. McGarvey & Matthews described the fishery database as being "recently reconstructed". What does that mean? *written answer 4 April:*

This refers to the two-stage process of (1) getting all the catches by numbers and weight entered into the database for the years 1983 back to 1970. After the qR model became used to generate indicators for both zones, Jim happened upon boxes of catch and effort monthly (hardcopy) forms from fishers sitting in a storage area. So a lengthy project was undertaken to enter all those records into the database. (2) Subsequently Jim waded back in and corrected, if I recall him telling me, about 800 records. So the time series for Cn Cw and E back to 1970 were those obtained after both of these stages were completed

17. Are the puerulus data still being collected? If so, are the recent data summarised anywhere? *written answer 4 April:*

Puerulus data are still being collected and are proving to be a valuable predictor of lagged pre-recruit abundance and CPUE. These data are relatively cheap to collect, can provide valuable insights (eg WA experience) and will be incorporated into the integrated model to enhance its predictive capacity. We consider that is essential to maintain this program and to expand the collector system in the NZ. A formal analysis of this data will be provided in the next stock assessment report. I have attached a file that summarises some of the data and provides some graphs. (Jim presented some this to industry last year)

18. Fishers at the meeting on 15 March described a program of bottom temperature data collection. Are those data in a form that could be used in the CPUE standardisation?
written answer 4 April:

Not really. Spatial variability in bottom temps is high. Data are available for only small area

Thanks in advance for your help. Number 13 is the most important; the rest are asked to ensure I understand what has been done.

Cheers
Paul

From: Paul Breen <p.breen@niwa.cri.nz>
To: ward.Tim@saugov.sa.gov.au
Subject: small request
Date sent: Fri, 5 Jul 2002 14:33:16 +1200

Tim:

I know you're busy, but could I please get the following:

From the most recent two seasons, catch in number, catch in weight, and total fishing effort.

Thanks in advance.
Cheers
Paul

From: "Ward, Tim (PIRSA - SARDI)" <Ward.Tim@saugov.sa.gov.au>
To: "'p.breen@niwa.cri.nz'" <p.breen@niwa.cri.nz>
Subject: RE: small request
Date sent: Fri, 5 Jul 2002 12:08:03 +0930

Paul,

season	*Cw*	*Cn*	*Effort*
2000	*846428.2*	*775837*	*687228*
2001	*673769.6*	*578951*	*622991*

Tim

From: Paul Breen <p.breen@niwa.cri.nz>
To: "Ward, Tim (PIRSA - SARDI)" <Ward.Tim@saugov.sa.gov.au>
Subject: RE: small request
Date sent: Fri, 5 Jul 2002 15:47:12 +1200

Tim:

Thanks for sending the numbers so quickly.

However, I'm having troubles. First, I note that the 2000 data are exactly the same as those I have from previous requests, so that's good. My notes indicate that the data I have are from Rick.

However, if I take the numbers you just sent, and divide Cw by effort or Cw by Cn, I don't get the same numbers as you sent earlier this week for CPUE or mean weight.

When I compare the data time series I have from earlier in the year, CPUE from the earlier series is an average 2% higher than in your recent spreadsheet; mean weight an average 3.6% lower, and PRI and average 7% higher with a lot of variability in the comparison.

I attach a spreadsheet with these comparisons. Why are the recent numbers different from what we've been working with? *written answer 5 July:*

> *Latest estimates that I sent you were based on daily data not seasonal summaries. Suspect this may explain some of the differences, but will check.*

Thanks in advance.
Cheers
Paul

Appendix 2: Sardi's Response to Draft Report 1 & NIWA's response

(NIWA's response is at the end)

Dr Tim Ward

Points of Agreement

SARDI agrees with NIWA's suggestion that an integrated assessment is required. SARDI noted the need for new assessment methods several years ago and took the lead on securing additional funding for this purpose, and as indicated previously to NIWA, PIRSA and the FMC, SARDI is developing an integrated assessment model of the type described by Maunder (1999, 2000) as part of a current FRDC study.

Preliminary results from that model will be available in July – 12 months ahead of schedule. This indicates the priority that SARDI has assigned to this project.

Once the model is developed staff on the FRDC project will focus on collecting and analysing data on the changes in technology that have occurred in the SA rock lobster fisheries over the last decade. NIWA correctly identified this as a priority for research in the NZRLF.

SARDI also agrees with NIWA's assessment that future assessments should more explicitly address the performance indicators in the management plan. In addition, future assessments for SZRLF and NZRLF will be presented as separate documents - in order to provide a better focus on the divergent research needs of each fishery. Future assessments will also report explicitly on non-core projects – ie peurulus and by-catch monitoring.

SARDI also suggest that future stock assessment reports should be comprehensive documents that are updated and upgraded each year. Current approach where reports are designed to simply provide updates on work in progress and not comprehensive assessments of the fishery – as is noted on the cover of all the reports – needs to be reconsidered. This approach can clearly cause difficulties for reviewers and others that are not involved with the fisheries on an ongoing basis.

SARDI also notes that the current approach was developed in conjunction with PIRSA and fishing industry in the context of the rigorous cost recovery negotiations that were conducted several years ago. This issue needs to be revisited.

SARDI also agrees with NIWA's recommendations that future assessments should:

- provide uncertainty estimates
- provide diagnostic results
- provide risk assessments
- use more of the available data
- address all issues in main results
- evolve towards an integrated model

Most of these improvements will be facilitated by the establishment of the integrated model.

SARDI also agrees that assessments should be better documented and peer reviewed. This is SARDI policy for all fisheries. The reason that recent RL assessments may not have been documented or reviewed as thoroughly as they should, may reflect the difficulties associated with having one scientist conduct stock assessments on two large fisheries.

Points of Divergence

Previous comments effectively summarises the areas where SARDI is in agreement with NIWA's assessment. What follows is an identification of the areas of disagreement and a presentation of the information supporting this position.

SARDI considers statements such as "*The fishery appears (with many caveats) to be stable [and] in a healthy position*" (p1, para 4) to be unduly optimistic and unreflective of the data and analyses provided by SARDI and discussed in the body of the NIWA report.

Several of the analyses presented in the SARDI reports clearly suggest that aspects of the fishery are cause for concern. NIWA explicitly accepts this fact in several places within their document, but then dismisses the analyses completely and excludes this information from their summary sections.

SARDI considers that NIWA's approach of dismissing these analyses (because they are suggestive but not definitive and/or do not give sufficient consideration to statistical significance or levels of uncertainty) to be inconsistent with a Precautionary approach.

The view that the analyses are suggestive of problems is consistent with the manner in which SARDI presented the results to industry. The accuracy of SARDI's assessment (ie that the performance indicators and other analyses suggest the status of the fishery is cause for concern) and the unduly optimistic nature of the comments provided by NIWA are borne out by data obtained during 2001/2002 and which I will present here.

Examples Where Conclusions Drawn By NIWA Are Inconsistent With Information Available

1. Effective Effort

p 15 para 6

"Prescott (2001) examines this question [of increases in effective effort] *further with a variety of analyses. In the first, it is demonstrated that traded pots have higher catch rates after the trade. This is suggestive but is not definitive with respect to whether the effective effort is increasing. The results depend on what is happening to the other pots in the fishery."*

SARDI's response to this statement is that the assumption that there has been no decrease in the catching efficiency of pots that have not been traded is reasonable. To dismiss the results of this analysis on this basis that the efficiency of other non-traded pots is not known (and thus may have decreased) is inappropriate. This approach is particularly difficult to understand in the light of information in Prescott and Xiao (2001) that suggests that the shift from owner-operators to skippers has also increased the catching efficiency of non-traded pots.

p 15 para 7

Next, Leslie analysis is used to estimate annual catchability from the regression of catch rate on accumulated catch, a standard tool. Only the last 12 weeks from each season are used. The annual estimates show an increase from 1991 to 2000 (Figure 16 of Prescott 2001), despite two MLS changes.

Prescott points out that the assumptions of the Leslie method are not met: mean size changes during the season (see Figure 13 of Prescott 2001); catchability and fishing patterns probably also change. The exploitation rate implied by the Leslie analysis (Figure 15 of Prescott 2001) is far higher than that estimated by the qR method - this implies that exploitation rate is over-estimated because catchability declines during the season. If both the seasonal change in catchability and the seasonal fishing patterns were the same in all years, then the analysis could show changes in catchability despite the failure of *assumptions. But there is no reason to assume that within-season changes have followed the same pattern in the years examined, and there is reason not to assume that fishing patterns have remained the same. It is unknown to what extent inter-annual changes confuse the picture, although the steady increase apparent in Figure 16 is suggestive.*

SARDI agrees that the results of the Leslie analysis are not definitive. However, as NIWA indicated the steady increase in relative q between 1991 and 2000 does suggest that there has been an increase in effective effort. It is not appropriate to simply ignore the results of this analysis because they are not definitive.

The problem with the approach taken by NIWA is exemplified by the following statement. Despite two analyses suggesting that effective effort has increased NIWA states:

Concerns expressed about serial depletion and increasing effectiveness of effort are not strongly supported by the data nor by the analyses presented, although they may be real.

SARDI would suggest a more balanced response would be along the following lines:

"Analyses presented in the assessments suggest that effective effort may have increased between 1991 and 2000, but additional analyses of this issue are required."

2. Catchability vs stock size

Prescott (2001) presents an analysis based on with two groups of fishers. "Group "A" fishers are thought to have not changed their fishing practices to the extent of the remaining Group "B" fishers". They have a lower CPUE than Group B. It is argued that, when catch rates are low, Group B increase their effectiveness, and the difference between the Groups' catch rates increases. The relation in Figure 18 tends to support this suggestion (p 16, para5).

Despite agreeing that Figure 18 supports the suggestion that some fishers can increase there effectiveness when biomass declines, NIWA goes on to dismiss this analysis (p 1 para 4: p 17, para 5) apparently on the basis that:

There is a widespread belief that catchability increases as stock size declines. This is called the Paloheimo & Dickie (1964) hypothesis, reviewed recently by Francis et al. (2001). They point out that few examples are published that show no relation between q and abundance, perhaps because "such 'negative' results are often considered unworthy of publication." They point that among the scarce examples where catchability ***increases*** *with abundance, leading to "hyperdepletion" of CPUE as opposed to "hyperstability", is the South Australian rock lobster fishery, discussed in a speculative passage in Hilborn & Walters (1992, pp. 190-91).*

Thus, the analyses provided by SARDI that suggest some fishers can increase their effectiveness when biomass declines are dismissed on the basis (i) that few other studies showing such results have been published and (ii) some speculative statements in Hilborn and Walters that suggest catchability may increase with increasing abundance. To dismiss the analyses on this basis is both nonsensical and non-scientific. It is another example of where conclusions drawn by NIWA are inconsistent with information available.

SARDI also disputes the suggestion that issues of (i) increases in effective effort and (ii) increases in q as biomass decreases are unrelated. We suggest that one of the key factors driving fishers to increase their catching efficiency is declining catch rates. This is especially important in input controlled fisheries, such as the NZRLF, and in times when catch rates are declining, as they have over the last few years in the NZRLF.

SARDI does not resile from its position that the information and analyses provided in Prescott and Xiao (2000) and Prescott (2001) suggest that there are significant problems with the fishery and that these issues need to be addressed as a matter of priority. Some of the reasons for maintaining this position are documented below.

Evidence Suggesting Niwa's Assessment Of The Fishery Is Unduly Optimistic

1. Catch-per-unit-effort

NIWA suggests that the decline in CPUE between 1999 and 2000 may be explained by increase in MLS or environmental factors (p 4, para 3; p 13, para 8).

The increase in MLS was introduced in 2000 and if this was the cause of the decline in CPUE recorded in Prescott and Xiao (2001) then many of the lobsters that were removed from the available biomass by the change in size limit should have grown above the legal limit by 2001.

If the increase in MLS was the reason for the decline, then the CPUE for 2001 should be higher than the CPUE for 2000.

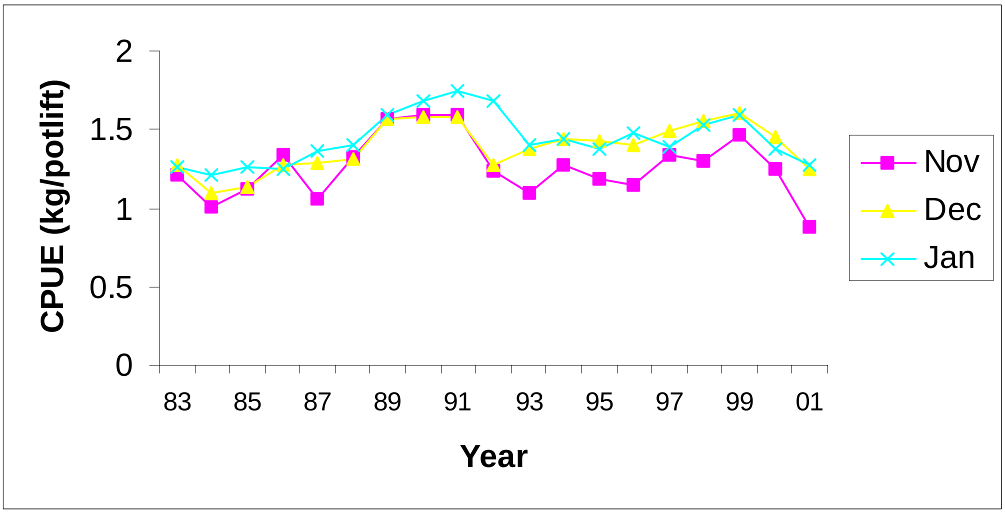

Figure 1. Latest CPUE data for the NZRLF.

Clearly the monthly CPUEs for 2001 have declined significantly below the 2000 levels.

Therefore: the increase in MLS does not explain the declines in CPUE.

Suggestion that decline in CPUE may be due to environmental factors is also dubious.

SARDI accepts that environmental factors such as swell height affect catch rates.

SARDI doesn't accept that environmental factors over last three seasons have been sufficiently different from previous years to explain recent declines in CPUE.

furthermore CPUE in SZRLF, which lies adjacent to NZRLF and is subject to similar environmental conditions, is currently experiencing record CPUE.

Therefore: changed environmental conditions do not explain the decline in CPUE.

SARDI assessment:

- decline in CPUE reflects decline in biomass
- stock clearly is outside 1992-97 reference ranges (see NIWA report p 12 para 3).
- action is clearly required to protect remaining biomass – as SARDI has recommended previously.

NIWA position on this issue is not supported by data available

Example of problems with NIWA report regarding assessment of CPUE data:

On p12 in para 4 NIWA state that:

“Catch rate (raw CPUE is shown) is less than the 1992-97 range, but this can partly be explained by the increase in MLS, which required the catch to be taken from a smaller set of the population than in previous years.”

In para 5 on the same page NIWA goes onto state:

We show biomass, estimated from our version of the qR model, because the implicit goal of the management plan is to maintain biomass within the 1992-97 range. Biomass in 2000 was lower than the 1992-97 range. However, this results in part from the change in MLS, which the model interprets as an especially low recruitment.

As discussed above, CPUE data for 2001 suggest that this assessment is incorrect and that the biomass in 2000 and 2001 was outside the 1992-97 range.

Another example of the unrealistically optimistic conclusions drawn by NIWA is shown on p 17, para 4. Dubious statements made in the body of the report that suggest the change in MLS explains why the biomass lies outside the 1992-97 range are changed in the summary of recommendations to the incorrect statement that:

currently available assessment suggests a stock within the 1992-97 reference ranges for the fishery indicators. **This assessment is WRONG.**

2. Recruitment

The indisputable decline in CPUE and biomass (alone) would not be cause for serious concern **IF** there was a large cohort(s) of pre-recruits about to enter the fishery.

Unfortunately this does not seem to be the case.

Despite the increase in MLS in 2000, which should have increased the number of lobsters below the legal size, the abundance of pre-recruits in 2000 fell below 1999 (and 1998) levels.

I cannot find any mention in the NIWA report of the fact that the 14% decline in pre-recruit abundance from 1999 to 2000 occurred despite the reduction in MLS and that the "real" decline in pre-recruit abundance was clearly much larger than suggested by the raw data.

This decline also followed a 16% decline in pre-recruit abundance between 1998 and 1999.

The lack of importance that NIWA seemed to assign to this issue is surprising.

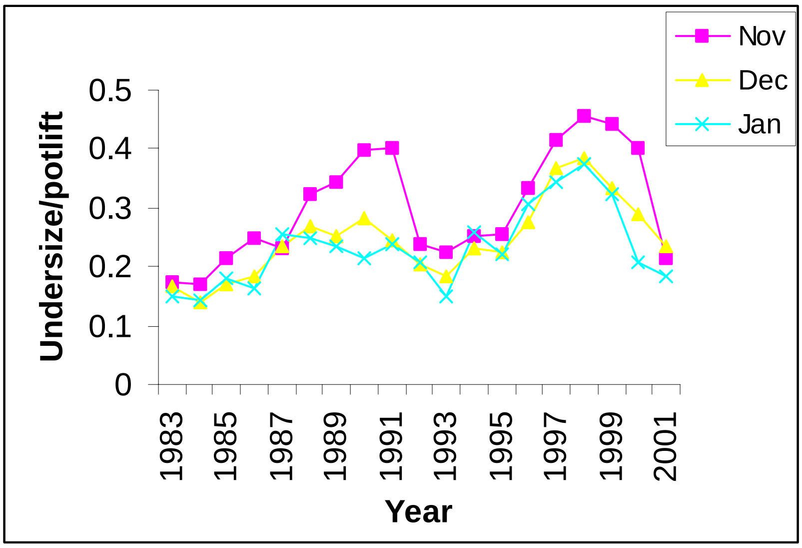

Figure 2. Recruitment index (undersize/potlift) by month.

The trend of declining pre-recruit abundance is continuing in 2001.

The increase in proportion of fishers with escape gaps from 46% in 98 to 53% in 2000 does not explain the decline in pre-recruit abundance. Discussions with fishers confirm that there are few small lobsters in pots. Similarly, a survey of recreation divers and SARDI research dive surveys suggests that the abundance of undersized lobsters in the NZRLF is the currently at the lowest level for many years.

It is clear that the last three years have comprised a period of low recruitment. Historical patterns (eg McGarvey and Matthews) suggest that we may be moving into an extended period of low recruitment.

Recent declines in recruitment combined with declines in CPUE/biomass clearly suggest a need to control extractions over next few years. In an input controlled fishery this means reducing the number of pot lifts. This is what SARDI has recommended. SARDI stands by this recommendation.

3. Other indicators

Mean weight has increased over recent years and continued to increase in 2001. This is partly due to the increase in MLS but also reflects low levels of recruitment over recent years. This provides additional evidence of the need to limit effort/extractions.

See above.

Summary and Conclusions

SARDI agrees that an integrated assessment model is required for the NZRLF and reiterate that such a model is being developed currently.

In the interim, performance indicators especially CPUE and pre-recruit index, must be used to assess status of fishery and direct management actions.

These indicators clearly show that a reduction in effort/extractions is required if indicators for the fishery, especially CPUE and biomass, are to be maintained at reasonable levels.

SARDI would add that 1992-97 catches were achieved as a result of unprecedented levels of recruitment and that attempting to maintain the catch for the NZRLF at the levels ---- achieved during that period is probably unrealistic.

NIWA's response:

Although we do not think a point-by-point comment on the SARDI paper is warranted, we should point out that we disagree with the general criticisms made, and we stand by the draft report.

In particular, we disagree that our summaries are unduly optimistic, if read in their entirety. We were careful to try to reflect what the analyses done by SARDI and data supplied actually tell us.

We also disagree that we have been dismissive of SARDI's analyses. We think some analyses are not robust and do not support the conclusions drawn from them. In response to SARDI's criticism we have strengthened our discussion of three such analyses in the text.

Towards the end, the SARDI response appears to defend what is essentially a **management** position rather than its assessment work. The two should, in our view, be kept separate.

Assessment is scientific, whereas management is political, and assessment should evaluate alternative management actions.

We do agree with, and have incorporated, the comment about the effect of the MLS change on the pre-recruit index.