WESTERN ROCK LOBSTER

LOW PUERULUS SETTLEMENT RISK ASSESSMENT

DRAFT REPORT FOR PUBLIC COMMENT

WORKSHOP HELD 1 AND 2 APRIL 2009
WA FISHERIES AND MARINE RESEARCH LABORATORIES HILLARYS

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Fish for the future

Consultation

The *Western Rock Lobster Low Puerulus Risk Assessment* report is designed to inform the fishing community, stakeholders and general public about the two day workshop that was held on the 1st and 2nd of April 2009 to assess the risks associated with the recent low puerulus settlements that have occurred in the western rock lobster fishery.

A draft report was released for public comment on 1 July 2009 and submissions closed on 30 July 2009. No submissions were received.

Where to get written copies of the report
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TABLE OF CONTENTS

Abbreviations and Acronyms **6**
Executive Summary **7**
Risk Assessment of Possible Causes of the Low Puerulus Settlement 9
Puerulus collectors 9
Environmental changes 9
Breeding stock 10
Other possible causes 10
Summary of Recommendations and Important Comments **12**
Puerulus collectors 12
Long term environmental changes 12
Breeding stock 13
Research Projects 14
Introduction **16**
Summary of Methodology **17**
Likelihood of Factors Assessed Causing the Low Puerulus Settlement **18**
Puerulus Collectors **18**
Conclusion 20
Recommendation 1 20
Changes in Environmental Conditions **20**
Scenario #1: A short-term environmental change 21
Conclusions 22
Scenario #2: Long term environmental changes 23
Conclusions 25
Recommendation 2 25
Recommendation 3 26
Recommendation 4 26
Recommendation 5 27
Breeding Stock Levels **27**
Physical oceanography 27
Biology 28
Breeding stock and increases in effective fishing effort: 28
Conclusions 31
Recommendation 6 32
Recommendation 7 33
Recommendation 8 33
Recommendation 9 33
Recommendation 10 33
Recommendation 11 34
Recommendation 12 34
Research Projects 34
General comments 34
Summary Assessment of Other Possible Causes **35**
Appendix 1 Long Term Puerulus Settlement **38**
Appendix 2 RA Programme, Facilitator and Panel **39**
Appendix 3 Consequence Tables **41**

Appendix 4 Variation from the Mean Puerulus Settlement 42
Appendix 5 FRDC Projects 45
Appendix 6 Fishery Dependent Breeding Stock Index 47
Appendix 7 Definitions 49
Appendix 8 Independent Breeding Stock Survey 50
Appendix 9 Annual Increases in Fishing Efficiency 52

Abbreviations and Acronyms

BS – Breeding stock.
CSIRO – Commonwealth Scientific and Industrial Research Organisation. CSIRO Division of Marine and Atmospheric Research undertake research on fisheries and the marine environment (amongst other things). http://www.csiro.au
DoF – Department of Fisheries is responsible, through the Minister for Fisheries, for the management of all fisheries in WA. http://www.fish.gov.au
FDBSI – Fishery Dependent Breeding Stock Index
FRDC – Fisheries Research and Development Corporation is the Commonwealth Government body that provides grants to undertake fisheries related research. An application has been put to FRDC to fund the proposed DoF deepwater ecological effects of fishing research project. http://www.frdc.com.au
IBSS – Independent Breeding Stock Survey
IOD – Indian Ocean Dipole
MEY – Maximum Economic Yield
RA – Risk Assessment.
RLIAC – Rock Lobster Industry Advisory Committee – a statutory committee under the Fish Resources Management Act that provides advice to the Minister for Fisheries.
WA – Western Australia.
WRLC – Western Rock Lobster Council is the industry organisation representing fishers in the western rock lobster fishery. www.rocklobsterwa.com.au
WRL / WRLF / WCRLF – Western Rock Lobster (WRL), Western Rock Lobster Fishery (WRLF) and West Coast Rock Lobster Fishery (WCRLF).

Executive Summary

Below average and very low puerulus settlements were observed in the western rock lobster fishery in 2006/07 and 2007/08 and 2008/09 respectively. These low settlements will have a major impact on the catch of rock lobsters three and four years after settlement, commencing in the 'reds' (March-June) fishery of 2009/10. They also have the potential to result in much lower breeding stock levels four to six years after settlement, if management action is not taken (or continued) to significantly reduce exploitation on the rock lobster stocks.

The current understanding of the influence of environmental factors (as measured by ocean temperature and wind conditions) on the last three puerulus settlements seasons is that:

- the below average settlement of 2006/07 was explained by environmental factors (water temperature and wind) at all settlement sites,
- the very low settlement of 2007/08 was not well explained by the environmental factors at most settlement sites, and
- the extremely low settlement of 2008/09 was not explained by the environmental factors at nearly all the settlement sites, in fact it went against the previous trends, based on the environmental conditions, i.e. settlement should have been average or better.

Due to the uncertainty of the cause(s) of the low puerulus settlements, particularly 2008/09 (e.g. as yet unknown environmental factor(s) or breeding stock effect), a risk assessment workshop was undertaken on 1 and 2 of April 2009.

The results of the risk assessment will be an important input into the current deliberations regarding what future research and management actions need to be taken over the next decade. They could include:

- an investigation of the possible causes of the low puerulus settlements – environmental and breeding stock,
- measures to protect and increase the breeding stock,
- measures to try and mitigate the impact of the low catches that will result from the very low puerulus settlements, and
- the development of a contingency plan in case the puerulus settlement in 2009/10 does not recover to normal levels.

The western rock lobster fishery is a data rich, with important data sets going back more than 60 years[1], therefore a large amount of information was presented over the two days of the risk assessment. The areas covered included lobster biology and life history (particularly breeding biology and larval stages), stock status (particularly puerulus settlement and breeding stock levels), increases in fishing efficiency, environmental factors affecting puerulus settlement, climate change effects on the fishery and aspects of physical and biological oceanography relevant to rock lobster life history stages.

[1] For example, catch and fishing effort from 1944/45, research log book data from 1963/64, puerulus settlement from 1968 and commercial catch monitoring from 1974. A detailed description of the data bases used to assess and model the fishery are available at http://www.fish.wa.gov.au/docs/frr/frr180/index.php?0401

The main concern regarding the recent low puerulus settlements was that the current long standing predictive model for puerulus recruitment (using sea temperature and wind conditions), which had previously provided a good explanation of the variations in settlement, did not adequately explain the recent settlement patterns, particularly the very poor settlement of 2008/09. The uncertainty regarding the cause of the low settlements represents a high risk to the fishery.

The workshop focused on examining the 'likelihood' of factors that could have caused the decline in puerulus settlement. The workshop concluded that the decline in settlement could have been caused by changes in environmental conditions and productivity in the eastern Indian Ocean, or a decline in the abundance of the rock lobster breeding stock, particularly in the northern region of the fishery, or a combination of these two factors.

The most important points presented at the workshop were:

- Long term environmental changes have been occurring in the eastern Indian Ocean, but the mechanisms by which they may be affecting puerulus settlement are, as yet, uncertain and in need of further investigation.
- Possible short term environmental changes, i.e. anomalies in the Indian Ocean Dipole and the lack of westerly (onshore) winds in August 2008, could have affected the 2008/09 puerulus settlement. They require further investigation.
- Preliminary results from oceanographic modelling suggest that, under certain environmental conditions, breeding stock areas in the north of the fishery could play a more important role in successful puerulus settlement than areas in the south.
- Breeding stocks in the far north of the fishery – Big Bank and the northern Abrolhos – have been significantly depleted. A reduction is also considered to have occurred in some of the other breeding stock areas in the northern and central regions of the fishery.
- It was suggested that the below average and low puerulus settlements that have occurred over the past three seasons could be part of a longer decadal decline in settlement, as maybe the case at the Abrolhos Is.
- If the environmental conditions this year, 2009, are average or favourable for puerulus settlement and it still remains very low, the likelihood that it was caused by breeding stock depletion (i.e. a stock and recruitment failure) would increase significantly.

From a stock and fishery perspective, managers and fishers do not have control over the environmental factors that impact on puerulus settlement, however they do have the ability to significantly influence the abundance of the breeding stock. Therefore, the Risk Assessment Panel (Appendix 2) was strongly of the view that managers and fishers should take significant short and long term action to protect the BS and to increase the level in areas that have been depleted[2], particularly in the northern region[3].

[2] The area south of Lancelin in Zone C is not considered to be critical as it is estimated to have adequate to good levels of BS.
[3] Big Bank and the northern Abrolhos are considered particularly important northern BS areas to protect.

The reductions in fishing effort/exploitation, which commenced in 2008/09, should be continued in 2009/10 and into future seasons, until breeding stocks are shown to be at 'safe' levels. This may require higher target and threshold levels of BS than were previously considered 'safe'. By significantly improving the abundance of the breeding stock, the high risk that it could be a critical factor causing the low puerulus settlements, should be virtually eliminated. An important aspect of reducing exploitation will be to ensure measures are implemented to protect the BS from being the focus of additional heavy fishing pressure, due to the significant decline in new recruits (legal size, immature lobsters) to the fishery that will be experienced for at least the next four seasons. Significantly reduced exploitation will also allow more lobsters to survive the vulnerable 'whites' migration period (Nov-Feb) and replenish the deepwater breeding grounds.

It is hoped that this Risk Assessment Report will help those charged with the management of the western rock lobster fishery and the fishing industry, to more clearly identify the high risk areas and thus plan more certainly for the future. The recommendations are provided as an input into the management process, which, as it is required to do, takes into account social and economic considerations, as well as those concerning the rock lobster stocks.

Risk Assessment of Possible Causes of the Low Puerulus Settlement

Puerulus collectors

The probability that the puerulus collectors were the cause of the low settlement counts of 2007/08 and 2008/09 (i.e. it was just measurement error) due to:

- different fibres, or
- collectors having been moved or interfered with, or
- puerulus settlement occurring in deepwater where there were no collectors,

was assessed as:

Likelihood: 1.0 – remote
Probability less than 2%

Environmental changes

It is very likely that both short term and long term environmental changes (physical and biological) are occurring in the eastern Indian Ocean. There was an offshore wind anomaly in August 2008, at the beginning of the puerulus settlement period; there have been three consecutive years of positive Indian Ocean Dipole (IOD) and for the first time a positive IOD coincided with a La Nina event in 2008.[4]

The likelihood / probability that short term environmental changes have in some way, as yet not fully explained, caused the low puerulus settlements of 2007/08 and 2008/09 was assessed as:

Likelihood – 2.5 (between Unlikely – 2 and Possible – 3)
Probability about 10 to 35%

[4] A positive Indian Ocean Dipole produces weaker onshore winds, which could affect the transport mechanism used by the late stage larvae and puerulus. La Nina events are associated with weak Leeuwin Currents and generally poorer puerulus settlements.

The likelihood / probability that long term environmental changes have in some way, as yet not fully explained, caused the low puerulus settlements of 2007/08 and 2008/09 was assessed as:
Likelihood – 3.5 (between Possible – 3 and Likely – 4)
Probability about 35 to 75%

Breeding stock
When annual increases in the level of effective fishing effort of about 8% (as determined from depletion analysis) are included in calculations of breeding stock (BS) levels, there is evidence that the levels have fallen to below the 1980s threshold level and to levels similar to the low levels seen in the early to mid 1990s (which raised serious concern at the time) and close to the limit reference point (i.e. 20% below the threshold level).

The decline in the BS in the Big Bank, northern Abrolhos and the coastal deep water BS areas in Zone B are of particular concern, as preliminary results from oceanographic modelling suggest that, under certain environmental conditions, the northern BS areas could be more important in producing successful puerulus settlement. There is also concern regarding the decline in BS levels in some other deepwater areas in Zone A and Zone C (only the area north of Lancelin).

The likelihood / probability that a decline in a particular part, or parts, of the BS have caused the low puerulus settlements of 2007/08 and 2008/09 was assessed as:
Likelihood – 3.0 – Possible
Probability – 20 to 50%.

Other possible causes
Four other possible causes of the low puerulus settlements were also assessed:

- **A combination of poor environmental conditions and a decline in breeding stock.**
  This is a combination of what were considered the two most important factors (as assessed above). Implications are the same as discussed for those factors.
  Likelihood: Likely - 3 to 4
  Probability about 35 to 75%

- **Disease affecting the phyllosoma larvae and / or the puerulus.**
  Currently there is no evidence to indicate disease is a significant factor.
  Likelihood: Remote – 1
  Probability less than 2%

- **Predation of phyllosoma larvae and / or puerulus at levels not previously experienced.**
  This could be due to something like a proliferation of jellyfish. Currently there is no evidence to indicate increased predation is a significant factor.
  Likelihood: Remote – 1
  Probability less than 2%

- **Ocean acidity**
  There is some information that there has been a small increase in the acidity of some of the world's oceans, thought to be produced by global warming. Whether

and how this could affect any of the rock lobster life history stages is unknown. A watching brief will be maintained and a further assessment will be undertaken when more information becomes available.

Likelihood: Remote
Probability less than 2%.

Summary of Recommendations and Important Comments

Puerulus collectors
Recommendation 1
The puerulus collector programme should be reviewed to determine if additional collector sites are required. It was suggested that the feasibility of establishing an additional collector site north of the Quobba Pt site be investigated. Quobba (which has only been monitored for the past four years) was the only site that did not show a decline in settlement in 2008/09. A more northern site (e.g. Ningaloo) would help to confirm (or otherwise) any possible northern shift in puerulus settlement.

Long term environmental changes
Recommendation 2
It is highly recommended that as part of FRDC Project 1 (Appendix 5), the water column productivity of the eastern Indian Ocean be assessed, in particular the use of satellite imagery to assess changes in chlorophyll A concentration and distribution over time and how this may be related to rock lobster larvae / puerulus development and survival.

Recommendation 3
In association with FRDC Project 1 (Appendix 5), it is recommended that some of *Southern Surveyor's* cruise time off WA in 2011 (or other vessel time, e.g. *RV Naturaliste*) be applied for, to investigate the productivity of the eastern Indian Ocean (e.g. phyto/zooplankton), in particular productivity / nutrition processes and mechanisms related to rock lobster larval growth and puerulus survival. Other aspects to investigate would be genetics of phyllosoma and puerulus, as part of the FRDC Project 4 on population genetics structure (Appendix 5).

Recommendation 4
Management and industry should urgently develop short, medium and long term plans to address the possibility that the recent short term declines in puerulus settlement may reflect a longer term environmental trend that could result in continued lower levels of puerulus settlement, which could flow on to produce breeding stocks that are below acceptable levels. In particular it is recommended that a plan of management be developed prior to the 2009/10 settlement period commencing, to cover the following scenarios:

a. the puerulus settlement of 2009/2010 returns to average or above average levels.
b. the puerulus settlement of 2009/2010 remains at a low level.

There should also be a review of the current management system to determine if it is the most appropriate under the circumstances, i.e. is there a need to change the management system so it can be more flexible and adapt more rapidly to future requirements? For example:

- have an agreement on the preferred fishing effort reduction strategy/mechanism that can be activated at short notice,
- would a quota system that directly controlled output (catch) be more effective than the current input (effort) control system,

- would greater use of closed fishing areas provide better protection for BS in critical areas?

Comment: The review of the management arrangements that is currently being undertaken, which includes developing plans along the lines suggested above and comparing input control and quota systems, is supported.

Recommendation 5

It is recommended that a review of the proposed management arrangements for 2009/10 and beyond, take place immediately after the August (or at the latest September) 2009 puerulus settlement figures become available.

Comment: The review should determine if the latest settlement figures, or results from a FRDC research project, require any changes to the management arrangements that have been implemented or are planned for the future. A timetable to review the results of each of the FRDC projects, as they become available, should be established immediately.

Breeding stock

Recommendation 6

That the managers of the fishery continue to act to protect all rock lobster BS and to increase, as rapidly as possible, the level in the areas of the fishery where it has declined[5] (particularly in the northern region), by reducing fishing effort/exploitation in 2009/10 and in future seasons. The target breeding stock saving that is required annually for each Zone of the fishery (i.e. to be achieved through fishing effort/catch reductions) should be specified.

Comment 1: The estimates of BS abundance should be presented as tonnages as well as the usual indices. This would help managers and fishers understand the amount of rock lobsters involved (tonnages) required to be left in the water to increase BS levels by a particular amount.

Comment 2: Large cuts in fishing effort are necessary to achieve relatively small reductions in exploitation rate, as rock lobster fishers appear to have an exceptional ability to offset them. To assist managers and fishers, the actual tonnage of lobsters an effort reduction leaves in the water should be provided.

Comment 3: Exploitation must be significantly reduced to ensure:

- a greater residual population of lobsters is left on the fishing grounds at the end of each fishing season, which translates to a more abundant BS, and
- more immature lobster survive the 'whites' (Nov-Feb) migration (they are most vulnerable to capture at this time) to replenish the deep water BS areas and become breeders.

Comment 4: To make it clear what level of catch the reductions in fishing effort are required to achieve, consideration should be given to expressing them as Total Allowable Catches (TACs) for the fishery and, if necessary, for each Zone of the fishery.

Recommendation 7

The Big Bank BS should remain fully protected, i.e. this part of the fishery should remain closed to fishing. A review of the BS levels should take place in three years.

[5] The area south of Lancelin in Zone C is not considered to be critical as it is estimated to have adequate to good levels of BS.

Recommendation 8
Special consideration should be given to providing additional protection for and to increasing (as rapidly as possible) the BS in the northern Abrolhos area.

Recommendation 9
More precise estimates of BS in the four areas assessed (Zones A, B, C and Big Bank) need to be developed. If the 'new' estimates of BS are shown to be below the threshold or limit reference point then appropriate management action should be undertaken to increase them to 'safe' levels as quickly as possible.
Comment 1: This would require a review of the magnitude of effective effort increases that have occurred over time, particularly in the BS areas and for them to be more precisely and robustly estimated and applied to the calculation of breeding stock abundance. The review of effective effort should investigate ways of quantifying by how much 'hot spot' fishing and a 'contraction/shrinking' of the population range, particularly in BS areas, affect the estimates of effective effort increases. This should be part of, or linked to FRDC Project 3 (measuring effective effort, Appendix 5).
Comment 2: There is concern that the annual level of effective effort increase in BS areas could be greater than the 8.5% estimated for the northern 'reds' fishery, using the depletion analysis.

Recommendation 10
The stock and recruitment relationship of the western rock lobster should be reviewed, with particular emphasis on data from 1995/96 to 2008/09, a period over which some puerulus collector sites appear to have a greater difference in the residuals from their mean settlements than has been the case in the past (Appendix 4), i.e. the possibility that some sites could be showing a declining trend in puerulus settlement needs to be further investigated.
Comment 1: More precise estimates of BS abundance, which incorporate the best estimates of the increases in effective fishing effort that have occurred in BS areas, should be used in the stock / recruitment analysis.

Recommendation 11
That monitoring and data analysis programmes be established to determine the impact of each of the management changes implemented in 2008/09 (and will be implemented in 2009/10 and future seasons) has had on the level of BS in each of the four areas of the fishery assessed (Zones A, B, C and Big Bank).

Recommendation 12
That a review of the commercial catch monitoring programme (which provides a measured of the BS abundance) be undertaken to assess whether it needs to be expanded into areas currently not covered, e.g. Big Bank, northern and southern Abrolhos BS areas.

Research Projects
- FRDC Project 1 – Identifying factors affecting the low western rock lobster puerulus settlement in recent years (Appendix 5) is supported.
- FRDC Project 2 – BS to puerulus source – sink relationship using an oceanographic larval advection model (Appendix 5) is supported.
- FRDC Project 3 – Investigating changes in fishing efficiency in the western rock lobster fishery (Appendix 5) is supported.

- FRDC Project 4 – Investigating rock lobster population genetic structure (Appendix 5) is supported.

Introduction

A risk assessment workshop was undertaken on 1 and 2 of April 2009 to investigate the possible causes of the below average puerulus settlement of 2006/07 and the very low settlements of 2007/08 and 2008/09 (Appendix 1) that have occurred in the western rock lobster fishery.

The current understanding of the influence of environmental factors (as measured by ocean temperature and wind conditions) on the last three puerulus settlements seasons is that:

- the below average settlement of 2006/07 was explained by environmental factors (water temperature and wind) at all settlement sites,
- the very low settlement of 2007/08 was not well explained by the environmental factors at most settlement sites, and
- the extremely low settlement of 2008/09 was not explained by the environmental factors at nearly all the settlement sites, in fact it went against the previous trends, based on the environmental conditions, i.e. settlement should have been average or better.

The main concern regarding the recent low puerulus settlements was that the current long standing puerulus recruitment model (using sea temperature and wind conditions), which had previously provided good predictions of the variations in puerulus settlement, did not adequately explain the last two very poor settlement years, particularly 2008/09. The uncertainty regarding the cause of the low settlements represents a high risk to the fishery.

The results of the risk assessment will be an important input into the current deliberations regarding what future research and management actions need to be taken over the next decade. They could include:

- an investigation of the possible causes of the low puerulus settlements – environmental factors and breeding stock,
- measures to protect and increase the breeding stock,
- measures to try and mitigate the impact of the low catches that will result from the very low puerulus settlements, and
- the development of a contingency plan in case the puerulus settlement in 2009/10 does not recover to normal levels.

Day one of the workshop (1 April 2009, Appendix 2) was an information day, where researchers gave presentations on western rock lobster biology and life history (particularly breeding biology and larval stages), stock status (particularly puerulus settlement and breeding stock) and increases in fishing efficiency, environmental factors affecting puerulus settlement, climate change effects on the fishery and aspects of physical and biological oceanography relevant to rock lobster life history stages. The western rock lobster is a data rich fishery with important data sets going back more than 60 years[6].

[6] For example catch and fishing effort from 1944, research log book data from 1965, puerulus settlement from 1968 and commercial catch monitoring from 1975. A detailed description of the data bases used to assess and model the fishery are available at http://www.fish.wa.gov.au/docs/frr/frr180/index.php?0401

Forty-six participants from the Department of Fisheries (DoF), Universities, rock lobster industry bodies and fishers, processors, conservation sector, and other stakeholders attended.

The second day of the workshop (2 April 2009, Appendix 2) was devoted to determining the likelihood of a range of potential factors being responsible for the low puerulus settlements. A panel of six experts (see Appendix 2) undertook the likelihood assessments, with the other 35 participants providing information and comment.

Summary of Methodology

The risk assessment for the low puerulus settlements was approached from the point of view that the 'consequence' is known and is considered to be major or extreme (see Appendix 3), i.e. the low puerulus settlements will have significant serious negative impacts on the rock lobster stocks and fishery. The low puerulus settlements of 2007/08 and particularly 2008/09, were not well explained by the environmental factors that had previously provided a good explanation for variations in settlement.

The risk assessment panel used the descriptors below to determine the likelihood of the factors assessed being the cause of the low puerulus settlements.

Value	Descriptor
Likely – 4	There is evidence that this is highly likely to be the cause (Probability of 50 - 100%)
Possible – 3	There is sufficient evidence to suggest this could have been the cause but there are some gaps in knowledge or some anomalies in the information (Probability of 20 - 50%)
Unlikely – 2	There is some evidence that this may have been the cause but it is not strong and/or there is other information that suggests it is not the cause (Probability of 2 -20%)
Remote – 1	Little or no evidence to support this and/or there is evidence that it is not the cause (Probability < 2%)

Following the presentations on rock lobster biology, monitoring programmes and oceanography, participants were asked to identify a list of potential causes for the reduced puerulus settlement. Seven possible causes were agreed by the panel to have some level of plausibility. The likelihood of each of the following factors causing the low puerulus settlements was independently assessed:

1. Observation error caused by the puerulus collectors
2. Changes in environmental conditions
    a. Short term
    b. Long term
3. A decline in the breeding stock

a. Over the entire fishery
b. In specific areas of the fishery

4. A combination of changes in the environment and a decline in the breeding stock
5. Disease affecting the eggs, larvae and / or puerulus
6. Increased predation of the larvae and / or puerulus
7. Increases in ocean acidity.

Likelihood of Factors Assessed Causing the Low Puerulus Settlement

The factors below were assessed as to their likelihood of having caused the low puerulus settlements observed in 2007/08 and 2008/09. A brief summary of the likelihood value estimated for each factor is provided, along with more detailed information regarding the assessment. The likelihood scores of **1 – remote** to **4 – likely**, as per the table above, have been used as the basis of the assessment.

Puerulus Collectors

Have the puerulus collectors been accurately recording the puerulus settlement, in particular the below average puerulus settlement of 2006/07 and the very low puerulus settlements of 2007/08 and 2008/09? That is, were the observed low settlements measurement errors, rather than an actual decline in settlement?
Low puerulus settlement counts could have been due to:

- different fibres being used on the collector panels;
- changes in position of collectors;
- interference with collectors; or
- collectors not being in the location where settlement occurred, i.e. settlement occurred in deeper water rather than shallow water.

Information and issues considered

Scenario #1: Different fibres
Has the use of different fibres on the puerulus collectors caused the low puerulus counts?

The use of two different fibres (Tanikalon and Boral Kinnear) came about when the production of Tanikalon ceased in the early 1990s[7] and a new fibre had to be gradually introduced from the mid 1990s, as the last of Tanikalon was used up. Trials have been undertaken over more than 15 years, using the two different fibres on different panels of the same collector and collectors with the different fibres side by side or in the same locations. The trials have shown that there is a difference in fibre "catch rates" of puerulus, but it is consistent. The Boral-Kinnear fibre catch rates are lower than that of the Tanikalon, however, they reflected the levels of settlement on the Tanikalon, but at a lower level.

The catch rates of the Boral-Kinnear fibre collectors are standardised against the Tanikalon puerulus counts, i.e. the numbers of puerulus are increased to bring them

[7] When it was discovered that Tanikalon production would cease, all remaining stocks of it were purchased to extend the time to test other new fibres against it.

up to what they would have been if they had been Tanikalon collectors. Since being introduced over 15 years ago, the Boral-Kinnear fibre collectors have "caught" puerulus well and consistently. All seven coastal sites where it is used gave low settlement counts in 2007/08 and 2008/09. In addition the collectors at the Abrolhos Is, where Tanikalon is still used, showed the same very low levels of settlement as the Boral-Kinnear sites.

Based on this evidence, it was considered a remote possibility that the replacement of the Tanikalon fibre with the Boral-Kinnear fibre over the past 15 years has resulted in the very low puerulus settlements observed in 2007/08 and 2008/09.

Scenario #2: The collectors have been moved or interfered with
Have the puerulus collectors been moved or interfered with, such that they produced the low puerulus settlements observed in 2007/08 and 2008/09?

Each collector is positioned by GPS and its position checked monthly. If on the rare occasion they have moved, e.g. due to storm surge, they are replaced in exactly the same spot. When their moorings are periodically replaced technical staff ensure the replacements are put in exactly the same position. There has not been any increase in collectors being 'out of position', in particular over the last three to four seasons.

Damage to the collectors is rare and Technical staff have not observed any increased level of damage (which could imply interference) over the past three or four seasons.

Based on this information, it was considered a remote possibility that there has been any movement or damage to collectors that would result in the very low puerulus settlements observed in 2007/08 and 2008/09.

Scenario #3: Collectors are not in the areas where settlement has occurred
Has the puerulus settlement occurred in deeper water where there are no collectors to monitor it?

A large majority of puerulus settlement is understood to take place in shallow water (>20m). However, some small juveniles (one and two years after settlement) have been found in deep water, indicating some settlement may also occur there, as they are unlikely to have migrated from inshore.

Research conducted in the past used collectors set in deeper water, i.e. set progressively out towards the edge of the continental shelf. No settlement was recorded on these deepwater collectors, either on the bottom, in mid water, or at the surface.

Preliminary results using traps covered with small mesh to retain one and two year post puerulus juveniles, does not indicate an abnormal (increased) number of puerulus settling in deeper waters.

Based on this information, it was considered a remote possibility that the puerulus settlements in 2007/08 and 2008/09 took place in deep water rather than, as normal, on the shallow inshore reefs.

Post puerulus
Anecdotal information from unofficial dive searches for the very small post puerulus / juvenile rock lobsters around some of the coastal collector sites found very few/none. This supports the low puerulus counts seen on the collectors in 2007/08 and 2008/09.

Conclusion

The probability that the puerulus collectors were the cause of the low settlement counts of 2007/08 and 2008/09 (i.e. it was just measurement error) due to:

- different fibres, or
- collectors having been moved or interfered with, or
- puerulus settlement occurring in deepwater where there were no collectors,

was assessed as:

LIKELIHOOD – 1.0 - remote
Descriptor: Little or no evidence to support this and there is evidence that it is not the cause.
Probability less than 2%.

RECOMMENDATION

Recommendation 1
The puerulus collector programme should be reviewed to determine if additional collector sites are required. It was suggested that the feasibility of establishing an additional collector site north of the Quobba Pt site be investigated. Quobba (which has only been monitored for the past four years) was the only site that did not show a decline in settlement in 2008/09. A more northern site (e.g. at Ningaloo) would help to confirm (or otherwise) any possible northern shift in puerulus settlement.
Comment: The review should also assess the precision of collector results when very low settlements are observed.

Changes in Environmental Conditions

Have there been changes in the marine environment that could have affected one or more of the life history stages of the rock lobster and caused the low puerulus settlements of 2007/08 and 2008/09?

It was noted at the beginning of the risk assessment process that the environmental changes that maybe contributing factors in causing the low puerulus settlements are likely to have been going on for some time, i.e. for a number of decades, as indicated for example by the long term increase in eastern Indian Ocean temperatures and the reduction in productivity of other species utilising the same marine system as the rock lobster, e.g. sea birds and southern bluefin tuna.

It was stated that if the eastern Indian Ocean system has been changing for some time, conditions, both physical and biological, could be less favourable for some rock lobster life stages (e.g. larvae and puerulus). From a ‘rock lobster’ perspective, these declining conditions could be masked by the high variability of the puerulus settlement.

It was suggested that a decline in the level of puerulus settling at some collector sites (in particular the Abrolhos Is.) might have started over a decade ago, i.e. from about 1995/96, when puerulus settlement reached very high levels. The possibility that there is a longer term downward trend in settlement as some sites needs further investigation. See the section "Annual variations from the mean puerulus settlement over time" below for further discussion.

Information and issues considered

Scenario #1: A short-term environmental change

Has there been a short-term environmental change, which is unlikely to reoccur in the future, which was responsible for the low puerulus settlements.

Wind anomalies

There is an indication that one of the low puerulus settlements (2008/09) may have been due to a short term environmental event, in that there had been a rare easterly (offshore) wind anomaly in the eastern Indian Ocean in August 2008, which was generated by large slow moving high pressure systems. Normally during August there are strong north westerly to south westerly winds (winter storms) that push water up against WA's continental shelf.

It was hypothesised that these anomalous easterly / offshore winds could have pushed the water mass that the late stage phyllosoma larvae and puerulus inhabit, further offshore and / or changed its productivity, thereby reducing the chances of the puerulus successfully reaching the coastal reefs to settle during August and the later important settlement months (September through to December). There was discussion as to why the August offshore winds would have had such a dramatic effect on all the later settlement months (virtually zero settlement occurred), when normal, mainly westerly wind conditions were experienced. Also the easterly wind anomaly did not occur in 2007/08. The importance of the August 2008 wind anomaly will be examined further using the oceanographic model being developed as part of FRDC Project 1 (Appendix 5).

Annual variations from the mean puerulus settlement over time

During the meeting, information was provided on the annual variation in the residuals from the annual long term mean puerulus settlement[8] for the five settlement sites with the longest time series. A composite coast-wide figure, combing the five sites was also provided. Raw data was provided for each site, along with model predictions of settlement taking into account two environmental factors (sea temperature, and Indian Ocean Dipole – winds). The model used these two known environmental factors to explain the variations in the residuals, i.e. to take into account the environmental effects (Appendix 4).

From a preliminary visual appraisal of the modelled residuals data, there does not appear to be a long term declining trend in puerulus settlement, but a more detailed analysis is required. However, the data did raise a number of concerns:

[8] The residuals from the annual long term mean settlement are obtained by subtracting the annual settlement value for a collector site from its long term mean value and expressing it as a percentage above or below the long term mean.

- *The 2008/09 settlement*: – 2008/09 had the largest deviation from the mean settlement at each of the collector sites (except one) and for the composite coast-wide figure, i.e. it was outside the range of historic data for all sites, but one (Appendix 4).
- *Coast-wide figure*: – For the first time there has been three consecutive years of low settlement (2006, 2007, 2008, Appendix 4). This has significant management implications for the stock and the fishery. If the 2009/10 puerulus settlement is also low, additional management action may be required to protect breeding stocks and to mitigate the impact of low recruitments (catch) to the fishery.
- *Abrolhos Is. site*: – The last three settlements at the Abrolhos have been very low, with the residuals for the last two seasons being the lowest on record and outside the range of the historic data.
- *Pre and post 1995 residuals*[9]:
    - Coast-wide – There appears to be far greater variation in the residuals post 1995 compared to pre 1995, which could indicate that the predictive model has become less reliable, i.e. the environmental factors used in the model are not 'explaining' as much of the variation in settlement as they were prior to 1995 (Appendix 4).
    - Abrolhos site – Post 1995 there are only four residuals above the mean and ten below the mean. Pre 1995 there were eight residuals above the mean and only three below (Appendix 4).
    - Dongara site – Post 1995 there are only four residuals above the mean and ten below. Pre 1995 there are nine residuals above the mean and only five below (Appendix 4).
    - Jurien, Lancelin and Alkimos sites – no trend pre and post 1995 (Appendix 4).

La Nina and the Indian Ocean Dipole

In 2008 a *La Nina* event (usually associated with a strong Leeuwin Current and good puerulus settlement) and a weak wind system (i.e. a positive IOD event, generally weaker westerly winds) coincided for the first time in almost 30 years. The weak wind system could have, in some way, counteracted the positive effect a *La Nina* usually has on puerulus settlement. As this was a one in 30 year event, it could be considered a short term environmental effect (i.e. it is unlikely to be repeated in the near future).

Conclusions

It appears likely that short term environmental changes have recently occurred (e.g. offshore winds in August 2008, La Nina and IOD) that may have affected physical and biological ocean processes in the eastern Indian Ocean. It is, as yet, unclear whether these short term changes could, in reality, be part of a long term trend.

The results of the 2009/10 settlement period will provide important information as to whether the recent low settlements (particularly 2008/09) can be explained by a short term environmental change.

[9] Post 1995 includes 1995.

The likelihood / probability that short term environmental changes have in some way, as yet not fully explained, caused the low puerulus settlements of 2007/08 and more particularly 2008/09 was assessed as:

LIKELIHOOD – 2.5 (between Unlikely – 2 and Possible – 3)
Descriptor: Unlikely – 2: There is some evidence that this may have been the cause but it is not strong and/or there is other information that suggests it is not the cause – probability of 2 – 20%
Descriptor: Possible –3: There is sufficient evidence to suggest this could have been the cause but there are some gaps in knowledge or some anomalies in the information – probability of 20 – 50%.

Probability of approximately 10 to 35%.

Recommendation

The recommendations regarding short term environmental changes are covered by the recommendations under long term environmental changes. The main difference being that if the cause is a short term change then management mitigation measures for the stock and the fishery can be more finite than if the cause was a long term change (i.e. producing an ongoing long term decline or 'step' decline to a lower base level of puerulus settlement). If a short term environmental change is the cause, exploitation (fishing effort) would need to be significantly reduced to:

- protect the BS during the years low recruitment will flow into the fishery to ensure fishing effort does not focus on BS areas,
- protect migrating lobster to ensure adequate replenishment of the breeding grounds, and
- lessen the impact in the poor catch years, i.e. push some catch from 'better' years into the predicted low catch years.

Scenario #2: Long term environmental changes

Has there been (and continues to be) long term environmental changes affecting the marine environment (a 'regime shift') that have caused the low puerulus settlements? More broadly, have there been long term environmental changes that threaten the viability of breeding stock, larvae and puerulus?

These long term changes include:

- increases in water temperatures,
- changes in wind and current strengths and directions, and
- a possible decline in east Indian Ocean productivity, caused by one or more of the factors listed above or as yet unidentified factors.

An important result of any long term changes could be that significant environmental anomalies will occur more frequently in the future. For example, changes in wind and current directions, patterns and strengths, which could affect transportation mechanisms and marine productivity (e.g. larval food supply), could increase in frequency. These changes could affect one or more rock lobster life history stages.

It was suggested that long term environmental changes could:

- produce a slow decline in puerulus settlement, with the normal large annual variations masking the decline, or
- be gradual and not impact on puerulus settlement until a 'tipping point' was reached, when the system could rapidly 'step down' to a lower level of puerulus settlement (i.e. significantly lower on average), with annual variations of unknown magnitude.

Physical and biological oceanographic information was presented[10] which highlighted the following:

a. Water temperatures in the Indian Ocean off the coast of Western Australia have been rising gradually for at least the past thirty years, mainly in the autumn/winter period (an ~ 1^{o}C increase). This is an indication that long term marine environmental and productivity changes may have been occurring.
b. For over a decade there has been an increase in the frequency of ENSO (*El Nino*) events, which are associated with weak Leeuwin Currents and relatively poor levels of puerulus settlement.
c. For the last decade there appears to have been more frequent westward wind anomalies in the equatorial Indian Ocean (associated with positive Indian Ocean Dipole events). This may have caused weaker westerly winds (which can move upper level oceanic waters towards the coast) in this region during the puerulus settlement period (late winter, spring and early summer). In particular the last three seasons which had below average and very low settlements (2006/07, 07/08 and 08/09) were all positive IOD events, which may have affected the wind system (i.e. generally weaker westerly winds).
d. There appears to have been some general increase in the eastern Indian Ocean northward surface wave energy fluxes compared to the eastward (towards the shore) energy flux. This may impact negatively, in some way, on the transportation of rock lobster larvae and puerulus towards the continental shelf and coast.
e. In 2008 a *La Nina* event (usually associated with a strong Leeuwin Current and good puerulus settlement) and a weak wind system (i.e. a positive IOD event, i.e. generally weaker westerly winds) coincided for the first time in almost 30 years. The weak wind system could have, in some way, counteracted the positive effect a *La Nina* usually has on puerulus settlement. While this could be considered a short term event, it is possible that the frequency of such events may increase.
f. There is increased biological productivity (as reflected in chlorophyll production) during *La Nina* events (when there is a strong Leeuwin Current, good puerulus settlement) and lower productivity during *El Nino* events (when there is a weak Leeuwin Current and generally poorer puerulus settlement). *La Nina* events could be associated with a greater and / or more nutritious food supply for rock lobster larvae. With fewer *La Nina* events occurring productivity in the eastern Indian Ocean could be declining, which could lead to less successful larval and puerulus development and survival. Late stage larvae need to have high energy reserves before they moult into the non-feeding puerulus stage, if the puerulus are to successfully swim across the continental shelf to the shallow inshore reefs.

[10] This is a brief summary. Some of the information presented was preliminary.

g. Information was provided on the annual residuals from the long term mean puerulus settlements[11]. The data, which was discussed above under *Scenario #1: A short-term environmental change* and provided at Appendix 4, does not appear to show a long term decline in puerulus settlement. That is, if long term environmental changes are occurring they do not appear, at this point, to be causing a declining trend in puerulus settlement. However, as discussed previously, long term environmental changes could have been proceeding without significant impact on puerulus settlement until a 'tipping point' was reached. The very low settlement of 2008/09, which is outside the historic data could herald such a 'tipping point'. There are also concerns that the annual residual data for some sites (the Abrolhos Is. in particular) may indicate a longer period of puerulus decline than just the past three seasons. This needs further investigation, along with any possible link to long term environmental changes.

Conclusions

It is very likely that long term environmental changes (physical and biological) are occurring in the eastern Indian Ocean.

The likelihood / probability that these long term changes have in some way, as yet not fully explained, caused the low puerulus settlements of 2007/08 and 2008/09 was assessed as:

LIKELIHOOD – 3.5 (between Possible – 3 and Likely – 4)
Descriptor: Possible –3: There is sufficient evidence to suggest this could have been the cause but there are some gaps in knowledge or some anomalies in the information – probability of 20 - 50%.
Descriptor: Likely – 4: There is evidence that this is highly likely to be the cause – probability of 50 - 100%)
Probability of approximately 35 to 75%.

Recommendations and Comments

Recommendation 2
It is highly recommended that, as part of FRDC Project 1 (Appendix 5), the water column productivity over time of the eastern Indian Ocean be assessed. Satellite imagery should be used to assess changes in chlorophyll A concentration and distribution and how this may be related to rock lobster larvae / puerulus development and survival.

Comment: FRDC Project 5 (Appendix 5), the collection of by-catch on the puerulus collectors, to see if other species that utilise the same marine environment as rock lobster larvae and puerulus show similar settlement patterns, is supported.

Comment: The continued expansion of the small mesh pots research to catch the small – 1 to 2 year old juveniles to monitor the abundance of post puerulus throughout

[11] The residuals from the annual long term mean settlement are obtained by subtracting the annual settlement value for a collector site from its long term mean value and expressing it as a percentage above or below the long term mean.

the fishery (particularly in deepwater, >36m) is supported. This project will provide a check that puerulus settlement indices from the collectors are still translating accurately to catch (particularly in years of low settlement).

Recommendation 3
In association with FRDC Project 1 (Appendix 5), it is recommended that some of *Southern Surveyor's* cruise time off WA in 2011 (or other vessel time, e.g. *RV Naturaliste*), be applied for to investigate the productivity of the eastern Indian Ocean (e.g. phyto/zooplankton), in particular productivity / nutrition processes and mechanisms related to rock lobster larval growth and puerulus survival. Other aspects to investigate would be genetics of phyllosoma and puerulus, as part of the FRDC Project 4 (Appendix 5) population genetics structure.

Comment: Information on changes in ocean acidity should be collected and a brief desktop study undertaken to assess whether it could have any implications for larval / puerulus development and survival. This was rated as a low likelihood.

Management and Industry
Comment: Long term environmental changes (e.g. more frequent ENSO events) are likely to have a different impact on each of the three Zones of the fishery. If low puerulus settlements become more frequent and the distribution of lobsters is affected by this in the same way as it has been in the past, the fishery is likely to contract northward and the impact on catches would likely be:

- lowest in A Zone,
- moderate in B Zone (greater as you move south), and
- greatest in C Zone, particularly in southern areas.

It should also be noted that there are indications that stocks in the north of the fishery (e.g. Big Bank and northern Abrolhos) are not being replenished at the normal rate. This could be due, for example, to ocean warming restricting the northern migration of juveniles and / or heavy fishing pressure on the migrating lobsters.

Recommendation 4
Management and industry should urgently develop short, medium and long term plans to address the possibility that the recent short term declines in puerulus settlement may reflect a longer term environmental trend that could result in continued lower levels of puerulus settlement, which could flow on to produce breeding stocks that are below acceptable levels. In particular it is recommended that a plan of management be developed prior to the 2009/10 settlement period commencing, to cover the following scenarios:

- the puerulus settlement of 2009/2010 returns to average or above average levels.
- the puerulus settlement of 2009/2010 remains at a low level.

There should also be a review of the current management system to determine if it is the most appropriate under the circumstances, i.e. is there a need to change the management system so it can be more flexible and adapt more rapidly to future requirements? For example:

- have an agreement on the preferred fishing effort reduction strategy/mechanism that can be activated at very short notice,
- would a quota system that directly controlled output (catch) be more effective than the current input (effort) control system,

- would greater use of closed fishing areas provide better protection for BS in critical areas?

Comment: The review of the management arrangements that is currently being undertaken, which includes developing plans along the lines suggested above and comparing input control and quota systems, is supported.

Recommendation 5
It is recommended that reviews of the proposed management arrangements for 2009/10 and beyond take place:

- immediately after the August (or at the latest September) 2009 puerulus settlement figures become available, and
- as soon as the results of each of the FRDC Projects that deal with environmental factors and population genetic structure become available (Projects 1, 2, 4 and 5, Appendix 5).

Comment: The review should determine if the latest settlement figures, or results from a FRDC research project, require any changes to the management arrangements that have been implemented or are planned for the future. A timetable to review the results of each of the FRDC projects, as they become available, should be established immediately.

Breeding Stock Levels

Have breeding stock (BS) levels declined to the point that they have caused the low puerulus settlements of 2007/08 and 2008/09?

The west coast rock lobster breeding stock was divided into the following areas to enable them to be assessed separately:

- The Big Bank and northern deepwater section of the Abrolhos Is (i.e. waters generally greater than 36m (>20 fathoms) north of North Island).
- Zone A (Abrolhos) 'core' area, i.e. waters around the island groups.
- Zone B waters generally greater than 36m (>20 fathoms) from 30°South latitude (just above Jurien Bay) to north of Kalbarri, which includes waters off Dongara and Geraldton.
- Zone C waters generally greater than 36m (>20 fathoms) from 30°South latitude (just north of Jurien Bay) to Cape Leeuwin, which includes waters off Jurien Bay, Lancelin, Fremantle, Mandurah and Bunbury.

Information and issues considered

The following information was presented[12]:

Physical oceanography

a. Preliminary results from modelling suggests that due to prevailing ocean transport systems, under certain circumstances, the breeding stocks in the northern part of the fishery may be more important for successful puerulus settlement than breeding stocks in the southern part of the fishery.
b. It was suggested that even though some areas of the northern breeding stock account for only a small proportion of total spawning biomass (e.g. Big Bank, northern Abrolhos Is), they might contribute a larger portion of the successful

[12] This is a brief summary. Some of the information presented was preliminary.

puerulus settlement. FRDC Project 1 (oceanographic / biological modelling) is exploring these questions in detail (Appendix 5).

c. Currently there is no firm evidence linking a particular BS area with successful puerulus settlement. FRDC Project 4 is evaluating the genetic structure of the western rock lobster (Appendix 5).

Biology

a. Most lobsters migrate in November-February (as 'whites'[13]) from the shallow inshore reefs, westward to deep water, three to four years after settling as puerulus. The great majority do not move more than 50 km. A small minority of lobster have a longer migration, with some individuals recording movements of over 400 km in a north westerly direction.
b. Lobsters generally reach maturity four or five years after settlement, however, lobster at the Abrolhos Is mature at a much smaller size, i.e. 10 to 20 mm smaller than on the coast.
c. Large females are more likely to have two batches of eggs in one season.
d. Size at maturity decreases from south to north in the fishery.
e. Size at maturity has declined significantly since the 1970s.
f. Size at migration has declined over time.
g. At present there is no evidence of a 'source – sink' relationship between BS and puerulus,[14] however, FRDC Project 4 (Appendix 5) will examine this issue further, using far more sophisticated DNA techniques than in the past.
h. The Abrolhos Is. area is a significant BS area, producing an estimated 50% of the eggs. Most egg production is from the undersize (<76 mm carapace) portion of the population. There are very few other areas in the fishery where a large proportion of the undersize lobsters spawn.[15]

Breeding stock and increases in effective fishing effort:

a. Two indices of breeding stock abundance are available:
    - those derived from catch rates from at sea monitoring of commercial catches, referred to as the Fishery Dependent Breeding Stock Index (FDBSI, Appendix 6). The FDBSIs are the indices on which the management of the breeding stocks are formerly based (see Appendix 7).
    - those derived from the Independent Breeding Stock Surveys (IBSS, Appendix 8), which are based on research catch rates in specific locations, and
b. Estimates of fishing efficiency derived from a number of sources[16] indicate that there has been an annual increase of about 5% (± 3%, range 2% to 8%) for the 'reds' part of the fishery (March to June). Analysis indicates that a very rapid increase has occurred since the mid/late 1990s (see depletion analysis Appendix 9).

[13] Newly moulted pale shelled juveniles.
[14] A source – sink relationship refers to determining if a particular part of the BS (which could be quite small) is responsible for all, or the majority, or some other proportion of puerulus that settle. If there is no source – sink relationship it may indicate that there is a good mixing of larvae with no particular BS area being more important than any other.
[15] Undersize spawners are, however, generally more numerous in the fishery now due to the decrease in size at maturity that has been occurring.
[16] That is depletion and catch prediction analysis and comparisons with standardised research catch rates (IBSS) and commercial catch rates.

c. The current worst case scenario is that effective effort could have increased by 8% annually. If this increase is applied to the calculation of BS indices based on fishers' catch rates (i.e. the FDBSI), they decline to levels below the thresholds of the early 1980s, but remain above the levels of the early 1990s (Appendix 6), i.e. they are below the thresholds but above the limit reference points (see definitions Appendix 7). If a BS level (index) falls below its threshold, immediate management action must be taken to increase it to above its threshold.
d. Further work, including depletion analysis, change in ratio (size vs undersize), index removal and puerulus-catch modelling, is being undertaken to try and obtain a more accurate and robust estimates of the annual increases that have occurred in effective effort.
e. It was suggested that if the annual increase in effective effort has been about 8%, it could have reduced the BS to a point where, under certain environmental conditions, it could have affected the level of puerulus settlement.
f. It is important to note that there are a number of factors that could affect fishing efficiency increases, including environmental conditions (e.g. water temperatures, swell conditions), timing of moulting and spatial distribution of fishing. These and other factors are being investigated as part of FRDC Project 3 (Appendix 5).
g. IBSS indices for the Abrolhos and southern and northern regions of the fishery appear to be above the early 1990s levels when the programme began (Appendix 3). These indices use research catch rates, which are not affected by increases in effective fishing effort. The BS levels in the early 1990s were considered to be critically low (see footnote 17).
h. There was some discussion regarding possible problems with the IBSS. The main problems identified being that the fixed locations at which the surveys are conducted:
    - may not sufficiently represent, the breeding stock (BS) areas that are the most significant in producing successful puerulus settlement for the fishery, e.g. Big Bank and the northern Abrolhos are not surveyed and could be such areas, and
    - are located in historically 'good' BS catch rate locations and therefore catch rates (abundances) in these areas could remain reasonably stable while other areas further from the 'core' of the fishery could experience significant declines in abundance, e.g. Big Bank and the northern Abrolhos regions and BS areas in deepwater between Dongara and Jurien.
i. There was discussion that annual effective effort increases might have been higher in the deepwater BS areas than for the fishery overall, or for the northern reds fishery (Mar-June), as new fishing technologies are considered more effective in deeper water. If this is the case, then the BS could be at levels lower than previously experienced in the fishery's history and significantly below the 1980s threshold level and at levels at, or approaching, the limit reference point[17]. If the BS declines to, or below the limit reference point, immediate management action must be taken to return it to above its

[17] The limit reference points for the rock lobster fishery's breeding stock are set 20% below the threshold levels, which are the BS levels estimated to have been present in 1980, before there was significant large scale and effective exploitation of the deep water breeding grounds.

threshold level (see Appendix 7 for definitions). Further depletion analysis, using daily research log book catch rates, is being undertaken to try and obtain a more accurate estimate of the effective effort increases that have occurred in the depths zone(s) where most of the BS is located. [18]

j. Researchers and some fishers consider the northern breeding stock to have been the most heavily depleted. In particular the deepwater stocks in the Big Bank region and the area north of North Is in the Abrolhos (A Zone). Fishers identified these two areas as being 'drastically' depleted and research information showed the catches and catch rates of undersize in the two areas had declined, indicating a decline in abundance and in replenishment (i.e. fewer small lobsters migrating into the area).
k. Some fishers have also identified that BS in ≥20-30 fm (>36-54m depth) generally in B Zone, had been 'drastically' depleted and that there was concern for BS in the southern Abrolhos (A Zone), south of Southern Group and the inshore area north of Kalbarri.
l. Researchers and some fishers where generally of the opinion that BS levels in the:
    - 'core' shallow water areas of the Abrolhos have remained stable over time, i.e. where the undersize BS is concentrated and is thought to account for up to 50% of the fisheries total spawning biomass;
    - northern region of Zone C – Jurien Bay to Wedge Is/Lancelin, had declined to a similar extent to the BS stock areas in Zone B (e.g. similar to areas offshore from Dongara); and
    - region south of Lancelin appeared to be in good shape – better the further south you go in Zone C.
m. Fishers believe that they are now far more able to target the better catch areas in deep water and keep their catches and catch rates up (i.e. 'hot spotting'), while the overall abundance in the area declines.
n. If further investigation indicates that there has been a decadal declining trend in puerulus settlement (commencing about 1995/96) it could be related (correlated) to a decline in breeding stock levels, particularly in the northern areas.
o. The comment was made that it maybe possible to mitigate a reduction in the success of larvae and/or puerulus due to long term environmental changes, by increasing the level of breeding stock (i.e. increasing egg and larval production), above what was previously considered a 'safe' level (i.e. the 1980s level, approx. 20% of virgin biomass).
p. It was suggested that environmental changes (e.g. water temperatures, currents, etc) could affect the 'strength' of the annual rock lobster migration. If not as many lobsters migrate and they do not migrate as far as normal, important breeding stock areas in deeper water and the northern extremity of the fishery may not be adequately replenished. This may already be the case with the Big Bank and northern Abrolhos Is. areas and other BS areas of concern identified by fishers.
q. Management measures implemented in 2008/09, in response to the low puerulus settlements, included a 35% fishing effort reduction in the 'whites' fishery (November-February) and about a 60-70% reduction in the 'reds' fishery (March-June). The Big Bank region was also closed to fishing.

[18] Log book catch and effort is recorded by depth.

Annual variations in puerulus settlement
Information was provided on the annual residuals from the mean puerulus settlements[19]. The data is discussed above under *Scenario #1: A short-term environmental change* and is provided in Appendix 4. A preliminary visual examination of this data does not appear to show a long term decline in puerulus settlement. If a decline in spawning stock has occurred it does not appear, at this point, to be causing a declining trend in puerulus settlement. However, the spawning stock could have been declining without having a significant impact on puerulus settlement until a 'tipping point' was reached. The very low settlement of 2008/09, which is outside the historic data could herald such a 'tipping point'. There are also concerns that the annual residual data for some sites (the Abrolhos in particular) may indicate a longer period of puerulus decline than just the past three seasons. This needs further investigation, along with any possible link to a decline in the spawning stock.

Conclusions

- When annual increases in the level of effective fishing effort of about 8% (as determined from depletion analysis) are included in calculations of breeding stock (FDBSI) levels, there is evidence that they have fallen below the 1980s threshold level and to levels similar to the low levels seen in the early to mid 1990s (which raised considerable concern at the time[20]) and close to the limit reference point (i.e. 20% below the threshold level).
- The decline in the BS in the Big Bank, northern Abrolhos and the coastal deep water BS areas in Zone B are of particular concern, as preliminary results from oceanographic modelling indicate that these northern BS areas could be more important, under certain environmental conditions, for the production of larvae that will successfully settle as puerulus in the fishery. There is also concern regarding the decline in BS levels in Zone A and Zone C – north of Lancelin.

The likelihood / probability that a decline in a particular part, or parts, of the BS have caused the low puerulus settlements of 2007/08 and 2008/09 was assessed as:

LIKELIHOOD – 3.0 – Possible
Descriptor: Possible –3: There is sufficient evidence to suggest this could have been the cause, but there are some gaps in knowledge or some anomalies in the information.
Probability – 20 to 50%.

The likelihood that a decline in a particular part of the BS could have contributed more to the low puerulus settlements than other BS areas was assessed as:

[19] The residuals from the long term mean settlement are obtained by subtracting the annual settlement value for a site from its long term mean value and expressing it as a percentage above or below the long term mean.
[20] A management package to address breeding stock decline was introduced in 1993. It consisted of: an 18 per cent pot reduction, a maximum size for females (105mm northern sector. and 115mm southern sector), an increase in the minimum size from 76 to 77mm (from 15 November to 31 January) and protection of setose and tar spot females at all times.

- **Big Bank and the northern deepwater section of the Abrolhos Is** (i.e. waters generally greater than 36 m (>20 fathoms) north of North Island).
  Likelihood 3 – probability 20 to 50%

- **Zone A (Abrolhos) 'core' area**, i.e. waters around the island groups. That is the areas were a very large proportion of the breeders are undersize.
  Likelihood 1 – probability less than 2%

- **Zone B** waters generally greater than 36 m (>20 fathoms) from 30° South latitude (just above Jurien Bay) to north of Kalbarri, which includes waters off Dongara and Geraldton.
  Likelihood 2.5 – probability approximately 10 to 35%

- **Zone C** waters generally greater than 36 m (>20 fathoms) from 30° South latitude (just north of Jurien Bay) to Cape Leeuwin, which includes waters off Jurien Bay, Lancelin, Fremantle, Mandurah and Bunbury.
  Likelihood 1.5 – probability approximately 2 to 10%.
  The likelihood / probability declines as you move south from Lancelin, as BS levels in this area are considered to be adequate to good. The probability increases as you move north of Lancelin, as BS levels in this area are believed to have been depleted to levels a similar to those in Zone B.

Recommendations and Comments

Recommendation 6

That the managers of the fishery continue to act to protect and increase (as rapidly as possible) the level of the BS in the areas of the fishery where it has been depleted (particularly in the northern region) by reducing fishing effort/exploitation in 2009/10 and in future seasons.[21] The target breeding stock saving that is required annually for each Zone of the fishery (i.e. to be achieved through fishing effort/catch reductions) should be specified.

Comment 1: The estimates of BS abundance should be presented as tonnages as well as the usual indices. This would help managers and fishers understand the amount of rock lobsters involved and the tonnages required to be left in the water to increase BS levels by a particular amount.

Comment 2: Large cuts in fishing effort are necessary to achieve relatively small reductions in exploitation rate, as fishers appear to have an exceptional ability to offset them. To assist managers and fishers, the actual tonnage of lobsters an effort reduction leaves in the water should be provided.

Comment 3: Exploitation must be significantly reduced to ensure:

- a greater residual population of lobsters is left on the fishing grounds at the end of each fishing season, which translates to a more abundant BS, and
- more immature lobster survive the 'whites' (Nov-Feb) migration (they are most vulnerable to capture at this time) to replenish the deep water BS areas and become breeders.

Comment 4: To make it clear what level of catch the reductions in fishing effort are required to achieve, consideration should be given to expressing them as Total

[21] The area south of Lancelin in Zone C is not considered to be critical as it is estimated to have adequate to good levels of BS.

Allowable Catches (TACs) for the fishery and, if necessary, for each Zone of the fishery.

Recommendation 7
The Big Bank BS should remain fully protected, i.e. this part of the fishery should remain closed to fishing. A review of the BS levels should take place in three years.
Comment: DoF's proposed sampling programme to monitor BS recovery in the Big Bank area is supported.

Recommendation 8
Special consideration should be given to providing additional protection for and to increase (as rapidly as possible) the BS in the northern Abrolhos area.
Comment: If this recommendation is implemented, a sampling programme to monitor BS recovery in this area would need to be established.

Recommendation 9
More precise estimates of BS in the four areas assessed need to be developed. If the 'new' estimates of BS are shown to be below the threshold or limit reference point then appropriate management action should be undertaken immediately to increase them to 'safe' levels.
Comment 1: This would require a review of the magnitude of effective effort increases that have occurred over time, particularly in the BS areas and for them to be more precisely and robustly estimated and applied to the calculation of breeding stock abundance. The review of effective effort should investigate ways of quantifying by how much 'hot spot' fishing and a 'contraction/shrinking' of the population range, particularly in BS areas, affect the estimates of effective effort increases. This should be part of, or linked to, FRDC Project 3 on measuring effective effort (Appendix 5).
Comment 2: There is concern that the annual level of effective effort increase in BS areas could be greater than the 8.5% estimated for the northern 'reds' (March-June) fishery, using the depletion analysis.
Comment 3: FRDC Project 3 looking at effective effort increases in the fishery (Appendix 5) is supported. The project should particularly focus on the magnitude of the increase in effective effort in BS areas.

Recommendation 10
The stock and recruitment relationship of the western rock lobster should be reviewed, with particular emphasis on data from 1995/96 to 2008/09, a period over which some puerulus collector sites appear to have a greater difference in the residuals from their mean settlements than has been the case in the past (Appendix 4), i.e. the possibility that some sites could be showing a declining trend in puerulus settlement needs to be further investigated.
Comment 1: More precise estimates of BS abundance, which incorporate the best estimates of the increases in effective fishing effort that have occurred in BS areas, should be used in the stock / recruitment analysis. FRDC Project 3 is reviewing effective fishing effort calculations and databases and evaluating new techniques (Appendix 5).
Comment 2: The review of the stock and recruitment relationship should be an important aspect of FRDC Project 2 – evaluating source-sink relationships and Project 3 – evaluating harvest rates and fishing efficiency increases (Appendix 5).

Recommendation 11
That monitoring and data analysis programmes be established to determine the impact of each of the management changes implemented in 2008/09 (and will be implemented in 2009/10 and future seasons) has had on the level of BS in each of the four areas of the fishery assessed (Zones A, B, C and Big Bank).
Comment 1: This will require the impact of pot reductions, days off, reductions in the maximum gauge and increase in the minimum gauge on the BS to be assessed.
Comment 2: It is recognised that any additional monitoring would need to be undertaken in a cost effective manner, given the cost-price squeeze the industry is experiencing.

Recommendation 12
That a review of the commercial catch monitoring programme (which provides the FDBSI) be undertaken to assess whether it needs to be expanded into areas currently not covered, e.g. northern and southern Abrolhos BS areas.
Comment 1: The review should consider how the programme should be used to monitor any increase (or change) of BS levels (e.g. due to management changes) in what are considered critical areas.

Research Projects
- FRDC Project 1 – Identifying factors affecting the low western rock lobster puerulus settlement in recent years (Appendix 5) is supported.
- FRDC Project 2 – BS to puerulus source – sink relationship using an oceanographic larval advection model (Appendix 5) is supported.
- FRDC Project 3 – Investigating changes in fishing efficiency in the western rock lobster fishery (Appendix 5) is supported.
- FRDC Project 4 – Investigating rock lobster population genetic structure (Appendix 5) is supported.

General Comments
- The possibility of using 'good' (accurate counts, not estimates) of BS numbers recorded in fishers' research logbooks, to provide a large and robust sample of the BS across the different areas of the fishery, should be investigated.
- Consideration should be given to developing new strategies for obtaining a wider spread of BS information across the fishery by using commercial fishing boats as 'research platforms'. For example, skippers and crews on selected boats from a variety of ports (particularly those fishing critical BS areas), could be trained to make daily records, from their first 10 pots, of BS catch rates and biological information (e.g. size and breeding status) and to accurately record location and possibly environmental data, such as temperature and swell.
- The research logbook programme should be reviewed to see if it is currently the most appropriate way to obtained the data that is required for stock assessment and management purposes under current and future conditions.
- Consideration should be given prior to the 2009/10 season of reviewing all the rock lobster data collection programmes and research projects to ensure they are delivering the information that is required to understand the changes that are occurring in the rock lobster stocks and to underpin the 'real time' management decisions that will need to be made in the future. (The WRLC stated that FRDC has 'earmarked' funding to support such a review.)

- Decreasing the legal maximum size protects more BS, but at the same time increases handling, which could have a negative impact on their survival and fecundity.
- Consideration should be given to establishing closed fishing areas in critical breeding stock regions, to protect BS and ensure they are not handled and have the maximum opportunity to breed successfully. Big Bank and the northern area of the Abrolhos could be considered.
- Increasing the minimum legal size to try to increase the abundance of the BS (particularly those above the maximum legal size) is only effective if the exploitation rate is significantly reduced at the same time (i.e. to give immature lobsters a greater chance to grow to sexual maturity/the maximum legal size). Any increase in minimum legal size would require a corresponding increase in escape gap height.
- It was suggested that consideration should be given to investigating the impact (biological, economic/marketing and social) of increasing the minimum legal size of lobsters across the fishery, to enable sufficient lobsters to breed at least once before being captured.[22] This would have a major impact on the 'whites' fishery (Nov-Feb), however, if natural mortality was low, the productivity of the stock could increase through growth. If the minimum size protected sufficient BS there may be no need for an upper size limit or to protect tar spot and setose females. With the right escape gap dimensions, few protected (i.e. smaller than the new legal size) breeding lobsters would be brought to the surface, thereby significantly reducing handling mortality and morbidity (e.g. reduced growth rate). This size limit concept tends to be the standard in most fisheries.
- The Abrolhos is an area of the fishery where a small increase in the legal minimum size (e.g. from 76mm to 77mm carapace) would significantly increase the abundance of the breeding stock. This is because breeding commences well below 76mm carapace at the Abrolhos, therefore virtually all 76-77mm females would be breeders.
- The industry would like to progress a project whereby BS are translocated from areas of high abundance in the south of the fishery (e.g. south of Fremantle) to areas in the north of the fishery, which they believe have been seriously depleted and could be critical to successful puerulus settlement, e.g. Big Bank. This project needs to be reviewed in the light of the Big Bank closure.

Summary Assessment of Other Possible Causes

Four other possible causes of the low puerulus settlements were also assessed:

- **A combination of poor environmental conditions (short or long term) and a decline in breeding stock.**
  This is a combination of what was considered the two most important factors (assessed in detail above). Implications are the same as those discussed above.
  Likelihood: Likely - 3 to 4
  Probability about 35 to 75%

- **Disease affecting the phyllosoma larvae and / or the puerulus.**
  Currently there is no evidence to indicate disease is a significant factor.

[22] For example, the new minimum size could be set to protect sufficient BS to safely maintain lobster populations without, or with little, reliance on breeding lobsters larger than the new minimum size.

Likelihood: Remote – 1
Probability less than 2%

- **Predation of phyllosoma larvae and / or puerulus at levels not previously experienced.**
  This could be due to something like a proliferation of jellyfish. Currently there is no evidence to indicate increased predation is a significant factor.
  Likelihood: Remote – 1
  Probability less than 2%

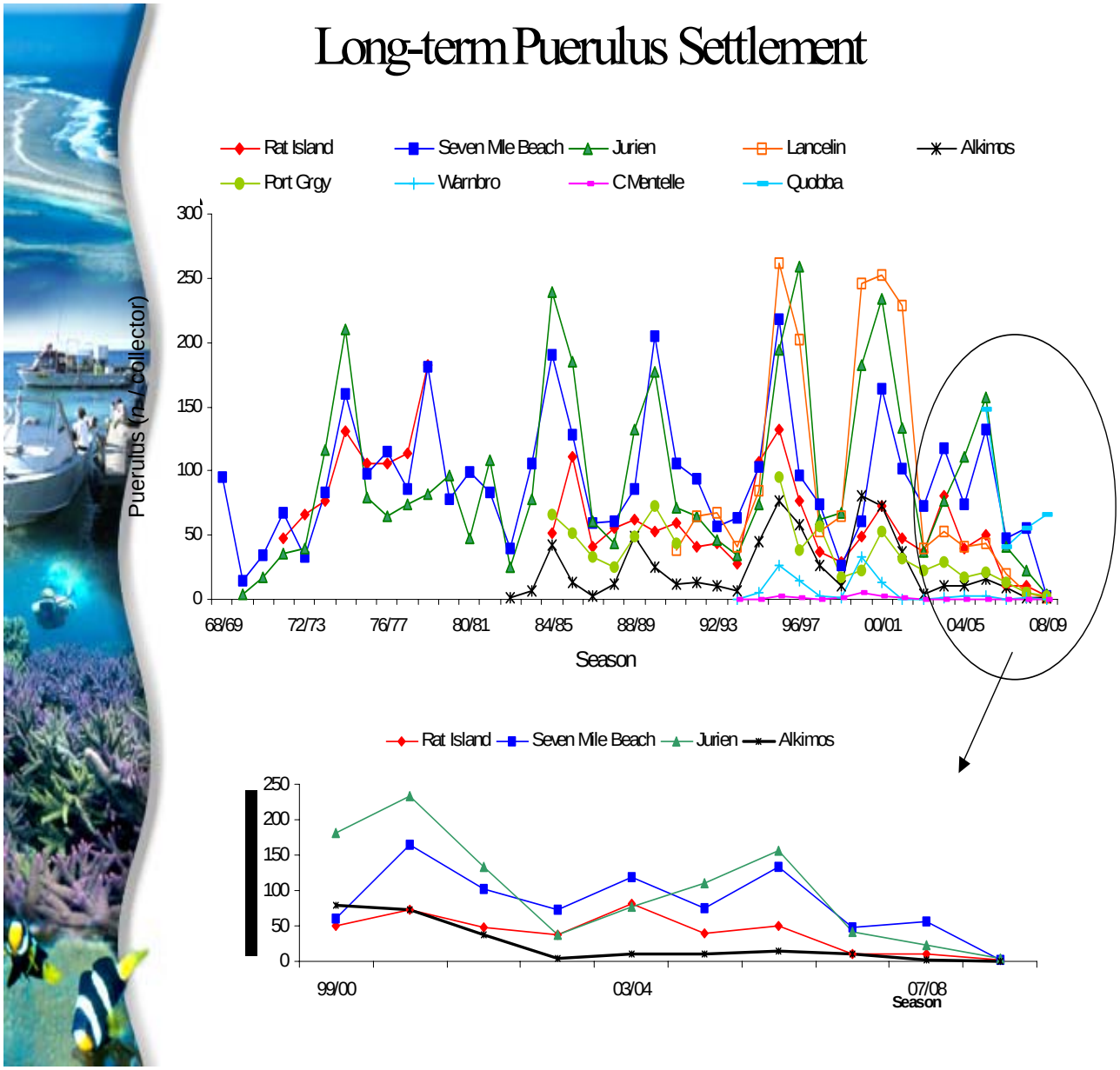
- **Ocean acidity**
  There is some information that there has been a small increase in the acidity of some of the world's oceans, thought to be produced by global warming. Whether and how this could affect any of the rock lobster life history stages is unknown. A watching brief will be maintained and a further assessment will be undertaken when more information becomes available.
  Likelihood: Remote – 1
  Probability less than 2%

Risk Assessment Panel Likelihood Scores

Likelihood of Factor Assessed Causing the Low Puerulus Settlement.	Scores	Av*
Puerulus Collectors		
Observation error caused by the puerulus collectors	1, 1, 1, 1, 1, 1	1
Changes in Environmental Conditions		
Short term	2.5, 2, 3.5, 2.5, 2.5, 2.5	2.5
Long term	3, 4, 3, 3.5, 3.5, 3.5	3.5
Decline in Breeding Stock		
Over the entire fishery	3, 3, 2.5, 3, 3, 3	3
Decline in Specific Areas of the Fishery		
Big Bank and the northern deepwater area of the Abrolhos Is	3, 3, 2.5, 3, 3, 3	3
Zone A (Abrolhos) 'core' area, i.e. waters around the island groups	1, 1, 1, 1, 1, 1	1
Zone B waters generally greater than 36 m	2.5, 2.5, 2, 2.5, 2.5, 2.5	2.5
Zone C waters generally greater than 36 m	1.5, 1.5, 1.5,1.5, 1.5, 1.5	1.5
Other Possible Causes		
Combination of changes in the environment and a decline in the breeding stock	3.5, 4, 3.5, 3.5, 3.5, 3.5	3.5
Disease affecting the eggs, larvae and / or puerulus	1, 1, 1, 1, 1, 1	1
Increased predation of the larvae and / or puerulus	1, 1, 1, 1, 1, 1	1
Increases in ocean acidity	1, 1, 1, 1, 1, 1	1

* To nearest 0.5.

Appendix 1 Long Term Puerulus Settlement



Appendix 2 RA Programme, Facilitator and Panel

Western Rock Lobster Risk Assessment Workshop
Low Puerulus Settlement
Hillarys

1 and 2 April 2009
(Commencing 9.30am)

Objectives

1. Review available information on the factors that may affect puerulus settlement, viz. breeding stock and environmental factors.
2. Identify the potential factors that may be affecting settlement that need further research or management responses.
3. Evaluate these factors using a risk assessment approach to help identify research and/or management priorities.
4. Identify research and/or management initiatives required to address the priorities.

Agenda and presenters

Day 1 Wednesday 1 April 2009 – Start time 9.30 am

Presentations (30 minutes + 15 minutes question time):

1.	Workshop welcome/introduction	15	Facilitator
2.	Biology of WRL	45	R Melville-Smith
3.	Puerulus and breeding stock assessment	45	S de Lestang
4.	Environmental factors affecting settlement	45	N Caputi
5.	CSIRO larval studies and aquaculture	45	B Phillips
6.	Current larval studies	45	A Waite
7.	Oceanography	45	M Feng
8.	General Discussion	30	Facilitator
9.	Description of risk assessment procedure and initial Fault Tree construction	60	Facilitator
10.	Morning tea (15), lunch (45), afternoon tea (15)	75	
	Total time	**7.5 hours**	

Day 2 Thursday 2 April 2009 – Start time 9.30am

11.	Facilitator recap on previous day	15
12.	Complete Fault Tree assessment for environmental issues	45
13.	Risk assessment evaluation of environmental issues	75
14.	Identification of new research and/or management strategies regarding environmental issues	45
15.	Complete Fault Tree assessment for breeding stock issues	45
16.	Risk assessment evaluation of breeding stock issues	75
17.	Identification of new research and/or management strategies	45
18.	Facilitator summing up	15
19.	Morning tea (15), lunch (45), afternoon tea (15)	75

Total time **7.25 hours**

Risk Assessment Facilitator
Dr Rick Fletcher – Director of Research, WA Department of Fisheries

Low Puerulus Risk Assessment Panel Members

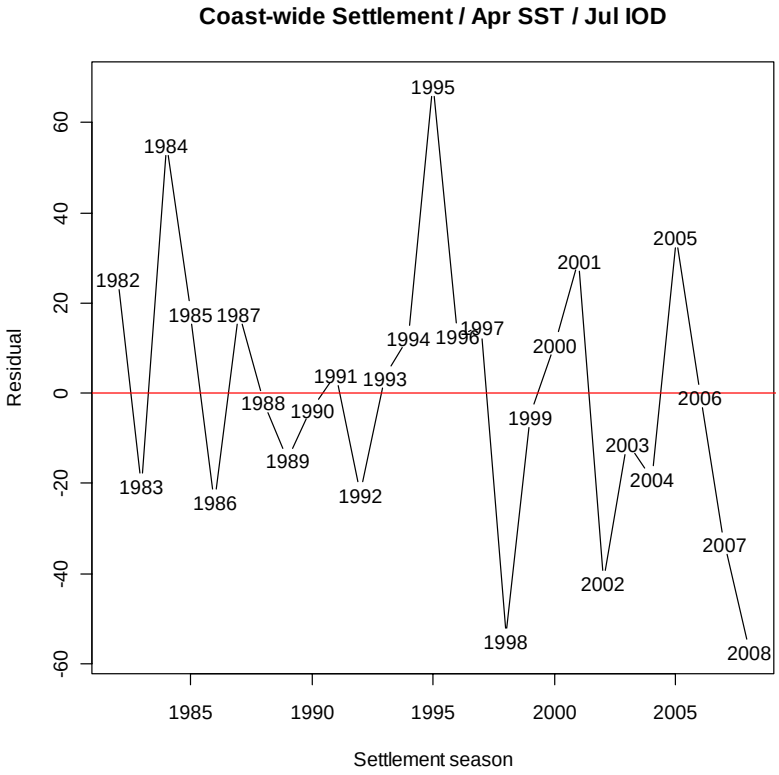
Dr Anya Waite	Environmental Systems Engineering University of Western Australia.
Professor Peter Rogers	Murdoch University (former CEO of the WA Department of Fisheries).
Dr Ming Fing	CSIRO, Wealth from Oceans National Research Flagship.
Associate Professor Stewart Frusher	Tasmanian Aquaculture and Fisheries Institute, University of Tasmania.
Professor Neil Loneragan	Fisheries Science, School of Biological Science and Biotechnology, Murdoch University.
Dr Nick Caputi	Research Division, WA Department of Fisheries.

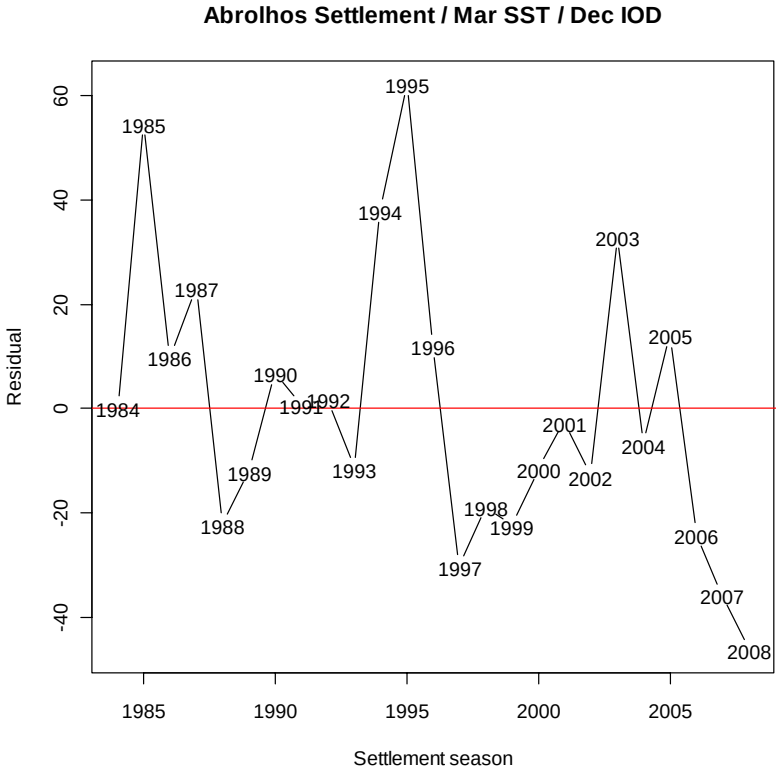
Appendix 3 Consequence Tables

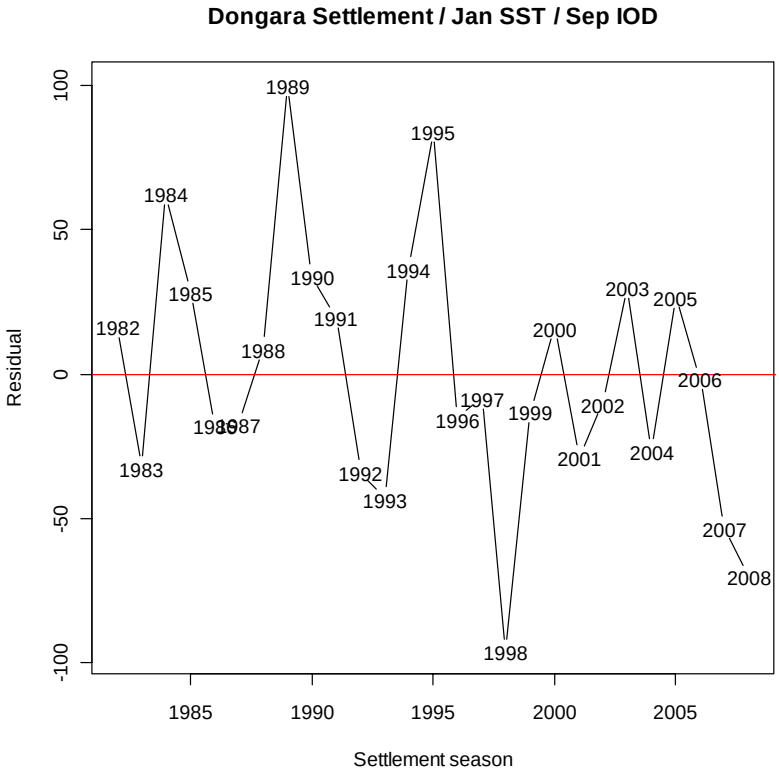
Risk Assessment Matrix

		Consequence Level			
Likelihood		**Minor**	**Moderate**	**Major**	**Extreme**
		1	**2**	**3**	**4**
Remote	**1**	1	2	3	4
Unlikely	**2**	2	4	6	8
Possible	**3**	3	6	9	12
Likely	**4**	4	8	12	16

Appendix 4 Variation from the Mean Puerulus Settlement






Dongara Settlement / Jan SST / Sep IOD
Residual
Settlement season
100
50
0
-50
-100
1985
1990
1995
2000
2005
1982
1983
1984
1985
1986
1987
1988
1989
1990
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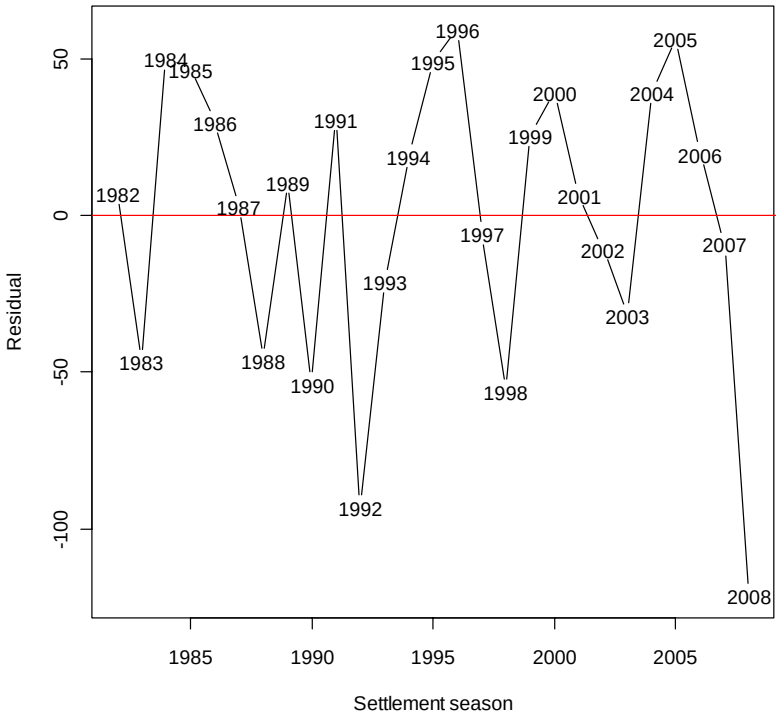
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008


Jurien Settlement / Feb SST / Sep IOD
Residual
Settlement season
50
0
-50
-100
1985
1990
1995
2000
2005
1982
1983
1984
1985
1986
1987
1988
1989
1990
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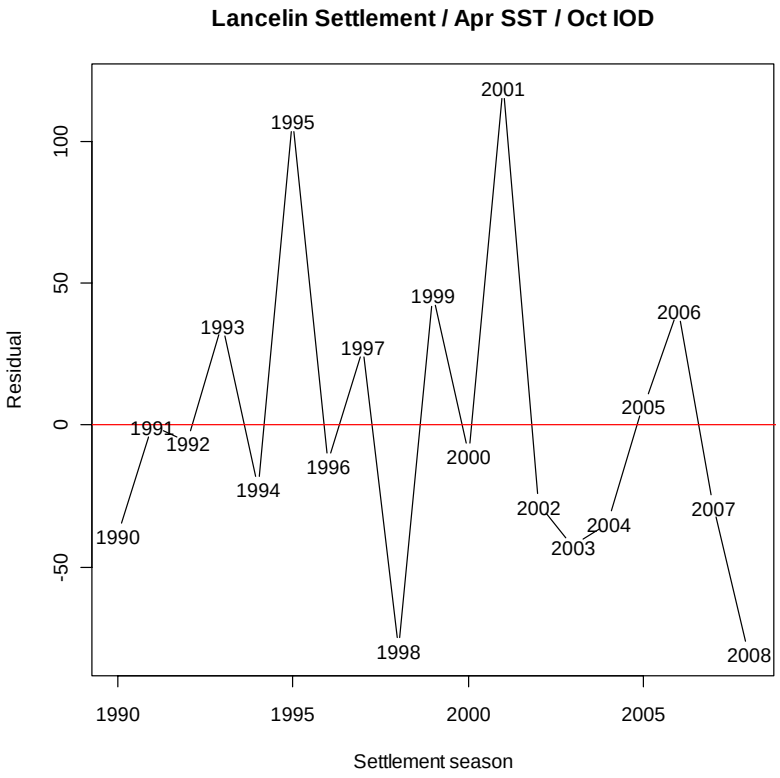
2007
2008


Lancelin Settlement / Apr SST / Oct IOD
Residual
Settlement season
100
50
0
-50
1990
1995
2000
2005
1990
1991
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1993
1994
1995
1996
1997
1998
1999
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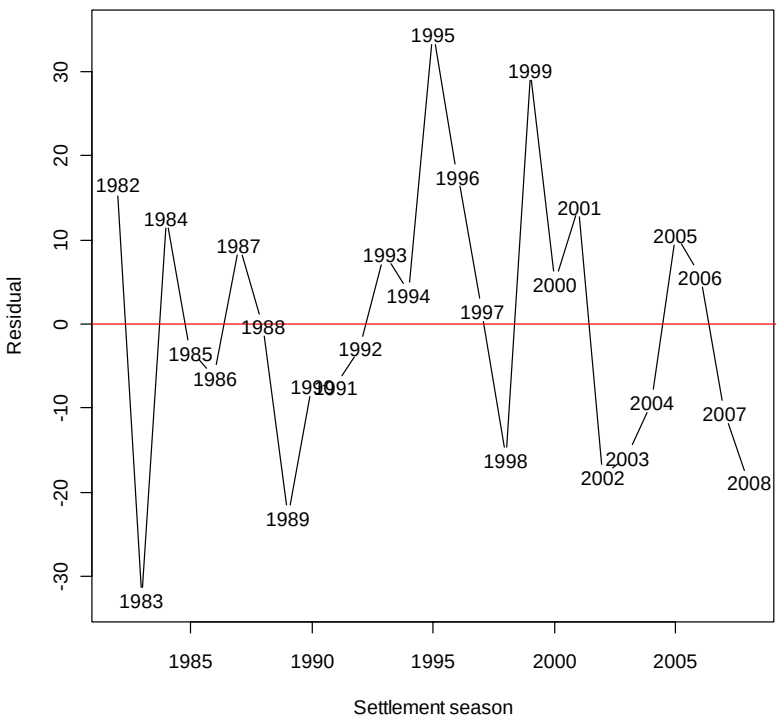
2001
2002
2003
2004
2005
2006
2007
2008


Alkimos Settlement / Apr SST / Dec IOD
Residual
Settlement season
30
20
10
0
-10
-20
-30
1985
1990
1995
2000
2005
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008

Appendix 5 FRDC Projects

FRDC PROJECTS TO INVESTIGATE
THE LOW PUERULUS SETTLEMENTS
(January 2009)

The five projects outlined below were submitted to the Fisheries Research and Development Corporation (FRDC) and were successful in securing funding. The objectives of the projects are to investigate various aspects of the possible causes and factors associated with the low puerulus settlements of 2007-08 and 2008-09.

Project 1 (FRDC 2009/018)

Identifying factors affecting the low western rock lobster puerulus settlement in recent years.

Objectives

1. To use a larval advection model and the rock lobster population dynamics model to assess the effect of the spatial distribution of the breeding stock on the puerulus settlement.
2. To assess environmental factors (water temperature, current, wind, productivity, eddies) and breeding stock affecting puerulus settlement.
3. To examine climate change trends of key environmental parameters and their effect on the western rock lobster fishery.
4. Provide industry (WRLC), RLIAC and Fisheries managers with an evaluation of relative impact of breeding stock and environmental effects on the puerulus settlement and its implications for management in the protection of the breeding stock.

Project 2 (FRDC 2008/087)

Evaluating source-sink relationships of the Western Rock Lobster Fishery using oceanographic modeling.

Objectives

1. To determine the relative contribution of larval production from different areas to the abundance and spatial distribution of puerulus settlement over 15 years using a larval advection model.
2. Provide industry (WRLC), RLIAC and Fisheries managers with an evaluation of source-sink relationships and its implications for management in the protection of the breeding stock

Project 3 (FRDC 2009)

Evaluating the use of novel statistical techniques for determining harvest rates and efficiency increases in the Western Rock Lobster Fishery. The project looks at using change-in-ratio and index removal to further examine fishing efficiency and harvest rates and pulls together some of the best mathematicians in this field, i.e. Professor Norm Hall[23], Assoc Professor Stewart Frusher[24] and Professor John Hoenig[25]

[23] Deputy Director Centre for Fish and Fisheries Research Murdoch University WA http://www.cffr.murdoch.edu.au/academic.html

Objectives

1. Assess current data sources and their potential for use in estimating harvest rates and efficiency increases in the western rock lobster fishery.
2. Evaluate whether additional sources of information are needed to produce more robust estimates of harvest rate and efficiency increase.
3. Assess whether the estimates of harvest rate and fishing efficiency are reliable and could be used to assist in the management of the western rock lobster fishery.
4. Provide industry (WRLC), RLIAC and fisheries managers with an evaluation of change-in-ratio and index removal techniques for determining harvest rates and efficiency creep.

Project 4 (FRDC 2009)

Evaluation of population genetic structure in the western rock lobster

Objectives

1. Develop additional new microsatellite markers for western rock lobster.
2. Test whether the adult population of western rock lobster is genetically homogeneous throughout its range.
3. Test whether the spatial genetic structure in the next generation of recruits (pueruli) matches the spatial genetic structure found in adults. (If so, this suggests spatial structure is due to limited dispersal or local adaptation).
4. Estimate effective population size of the western rock lobster and test for severe bottlenecks in population size.

Project 5 (FRDC 2008)

Assessing possible environmental causes behind the reduced colonization of puerulus collectors by a wide suite of species.

Objectives

1 Begin monitoring the community composition of marine flora and fauna along the Western Australian coastline during this current poor settlement period.

2 Develop standard methodology for monitoring the spatial and temporal variability in the settlement of marine flora and fauna.

3 Determine what environmental parameters may be linked to the majority of variation in the floral and faunal communities colonizing puerulus collectors, focusing on those relating to puerulus settlement.

4 Identify indicator marine flora and fauna species for monitoring the influences of environmental change on Western Australian marine environment.

5 Detect any known or potential introduced marine pests within the Western Australian environment.

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[24]Program Leader Sustainable Fisheries, University of Tasmania
http://fcms.its.utas.edu.au/scieng/mrl/pagedetails.asp?lpersonId=3047

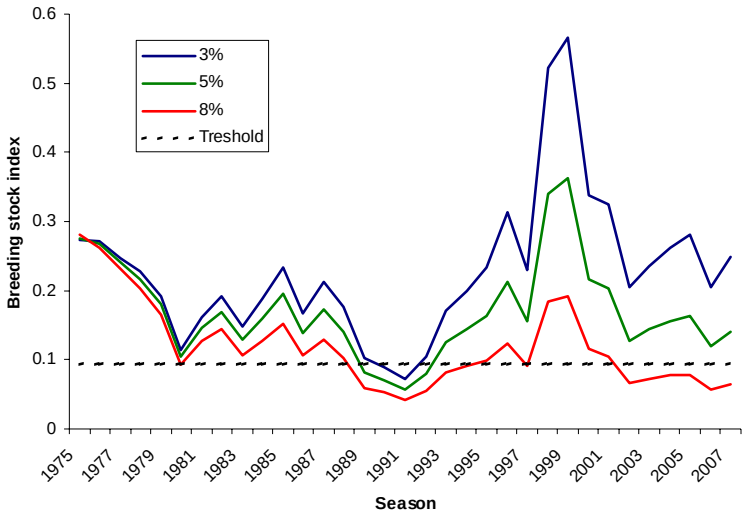
[25]Professor of Marine Science Virginia Institute of Marine Science USA
http://www.vims.edu/fish/faculty/hoenig_j.html.

Appendix 6 Fishery Dependent Breeding Stock Index

Fishery Dependent Breeding Stock Index (FDBSI) based on the catch rates derived from the at sea commercial catch monitoring programme. The annual level of effective effort increase applied to the catch rates is show in the box above the graphs.

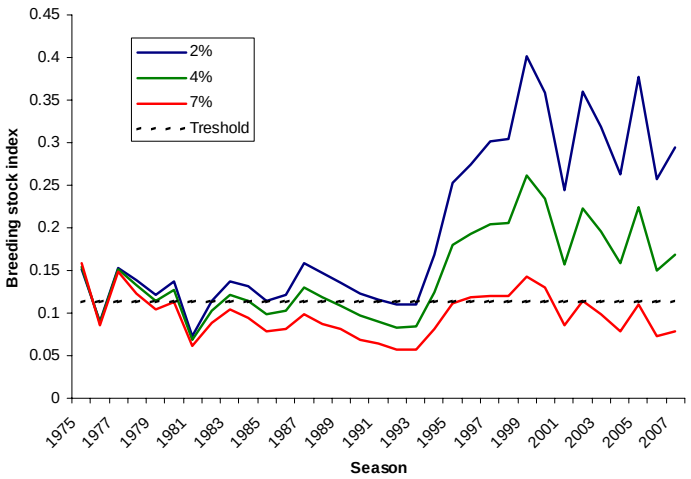
North Coast BSI (Commercial Monitoring)

(Dongara & Jurien)

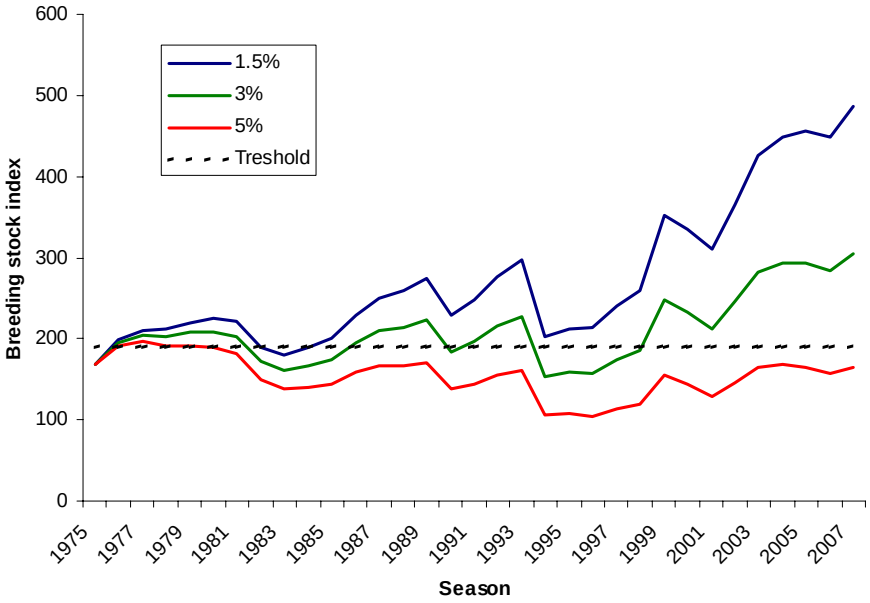


South Coast BSI (Commercial Monitoring)

(Lancelin & Fremantle)



Abrolhos IBS (Model derived)



Appendix 7 Definitions

- **Limit** – An upper or lower boundary outside of which immediate significant management action is required.
- **Threshold –** An upper or lower boundary outside of which management action is required.
- **Target –** The optimum value for the fishery from a biological and/or economic perspective.

PROPOSED OBJECTIVES AND DEFINITIONS OF THE DECISION RULES FOR THE WESTERN ROCK LOBSTER[26]

1. *That the Management Objective for the West Coast Rock Lobster Fishery remains as "That management arrangements maintain or restore as the case may be, the abundance of breeding lobsters at or above the levels in 1980."*

2. *That the indicator used to measure performance against the breeding stock management objective is the Fishery-Dependent Breeding Stock Index (FDBSI)*[27]*.*

3. *That the breeding stock reference points based using FDBSI indicator for Zones C and B (south and north of 30°S latitude, respectively) are:*

Target	*FDBSI greater than the level in 1980*[28]*.*
Threshold	*FDBSI = FDBSI in 1980.*
Limit	*FDBSI = 20% below the threshold level.*

[26] From the discussion paper on the *Decision Rules*, which is in final draft form. It is anticipated that it will be released for public comment at the end of June 2009.

[27] The FDBSI is derived from the commercial monitoring programme where research staff go on board commercial vessels and measure a proportion (usually 100%) of the catch. This program currently operates from six locations for each month that the fishery is open. The breeding stock data are combined into a northern coastal index (Dongara and Jurien) and a southern coastal index (Lancelin and Fremantle). These indices are smoothed using a weighted 3-year moving average to enable the underlying trends to be more clearly identified. A great strength of this index is the large number of pots (number of rock lobsters) that are sampled across the entire fishery. A full description of the data bases and analysis used can be found on p61 of the *Stock Assessment of the West Coast Rock Lobster Fishery* (Draft) www.fish.wa.gov.au/docs/frr/frr180/index.php?0401

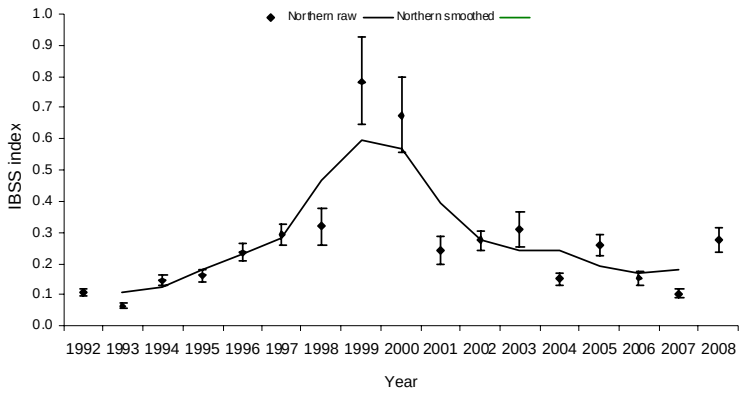
[28] The breeding stock level at about 1980 was chosen as it represented an adequate level of breeding stock that was not subject to very high levels of fishing due to the introduction of technology that assisted in the improving efficiency of deep water fishing. It also represented a breeding stock where recruitment variability was mainly due to environmental conditions.

Appendix 8 Independent Breeding Stock Survey

Independent Breeding Stock Survey (IBSS) Index based on research catch rates at specific locations

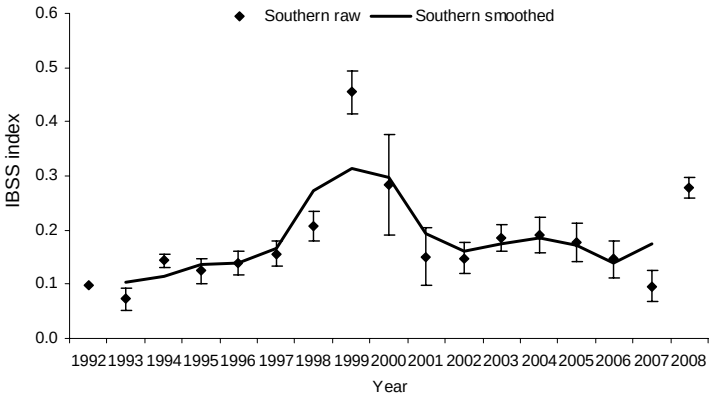
North Coast (IBSS)

(Dongara & Kalbarri)

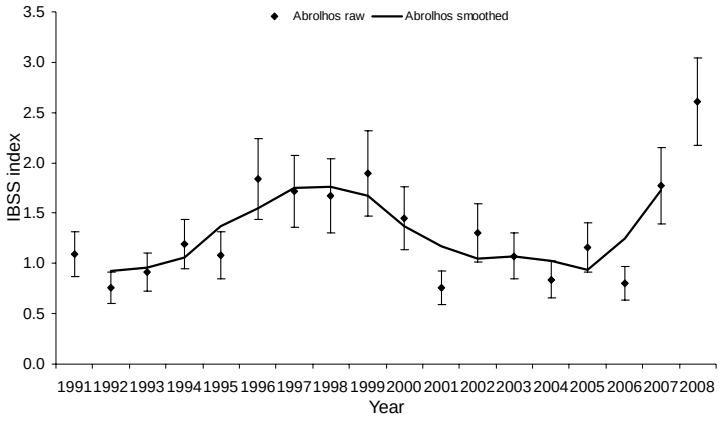


South Coast (IBSS)

(Jurien, Lancelin & Fremantle)



Abrolhos (IBSS)

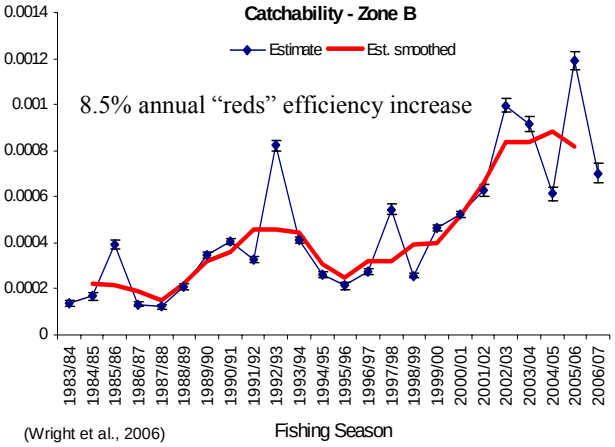


Appendix 9 Annual Increases in Fishing Efficiency

Annual increases in fishing efficiency as estimated using depletion analysis of catch rates during the 'red' part of the fishery (March to June).

Fishing Efficiency

- Initial "reds" estimates based on monthly trends (Wright et al., 2006).
- Developing further to examine on finer scale
- Using weekly / daily depletion?
- Change-in-ratio / Index removal (FRDC project)



(Wright et al., 2006)