Improved understanding of economics in fisheries harvest strategies

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PROJECT OBJECTIVES:

1. Increase the level of understanding of industry and fisheries managers on the role and benefits of fisheries economics in fisheries management.
2. Production of a short (5-8 minute) video on economics in fisheries harvest strategies.
3. Production of a Power Point presentation on the economics in fisheries in harvest strategies.

OUTCOMES ACHIEVED AND PLANNED

The planned outcome is that industry has a more effective understanding of the benefit of considering economics in the management of fisheries. This will increase "buy-in", and also result in higher level of discussions at fisheries assessment meetings, which will in turn lead to improved harvest strategies and better managed fisheries. An educational video, brochure and Power Point have been produced and will be distributed widely prior to submission of the Final Report. The video is hosted on a public YouTube channel as a part of the video series developed as a part of FRDC Project 2010-306 "*Empowering Industry through Improved Understanding of Stock Assessments and Harvest Strategies*".

LIST OF OUTPUTS PRODUCED

1. Video – https://youtu.be/rsnXbEQz54I
2. Brochure – Appendix 2
3. Power Point presentations – Appendix 3

PROJECT SUMMARY

Increased understanding amongst the commercial fishing industry of economic considerations in the management of fisheries was considered a high priority by the CRC, who identified a need to get better support for and implementation of harvest strategies based on Maximum Economic Yield. Experience has shown that video is an effective medium for educating the fishing industry, providing the required technical information is at a level that suits the target audience, with imagery of commercial fishing operations to hold the audience's focus.

This project has produced an educational video, brochure and Power Point presentation that will be distributed widely prior to submission of the Final Report to fishery peak bodies, government departments, educational institutions and environmental NGOs to improve their understanding of fisheries economics. The video is hosted on the YouTube channel developed for FRDC Project 2010-306 "***Empowering Industry through Improved Understanding of Stock Assessments and Harvest Strategies***", and the brochure and Power Point are attached as appendices.

ACKNOWLEDGEMENTS

The project was supported by the Australian Seafood CRC. It involved collaboration between Fishwell Consulting, Institute for Marine, Antarctic Science (IMAS), Biomedia, Thalassa Consulting and SARDI Aquatic Sciences. We are grateful to Jeff Cockman (WA Rock Lobster fisherman) for providing an interview and allowing us to film on board his vessels. Dr Len Stephens and Dr Rick McGarvey provided comments on the script. We would also like to thank the owners, skippers and crews of the following vessels on which we filmed for FRDC Project 2010-306 "***Empowering Industry through Improved Understanding of Stock Assessments and Harvest Strategies***", and some of which has been included in the economics video: Petuna Endeavour (Petuna Sealord Deepwater Fishing PTY LTD), Western Alliance (Corporate Alliance Enterprises PTY LTD), Shoalhaven (Tony Lavalle), Nungurner (Wayne Cheers), Karlene Maree (Russell 'Frosty' Frost), Diana (Mures Fishing PTY LTD) and Game On Charters (Darren Dodge). Additional footage was provided by the Marine Stewardship Council (filmed by Jason Thomas), and the Fisheries Research and Development Corporation. We also thank Charlotte Whitby for graphic design of the brochure.

Introduction and Background

Most of Australia's Commonwealth and State fisheries are managed with due consideration of optimising returns to the community from utilisation of those fisheries resources. The Commonwealth Harvest Strategy Policy (DAFF 2007) is a key policy that guides the harvest of commercial species in all Commonwealth fisheries. It provides for a strategic, science-based approach to setting fishing targets, limits and associated decision rules for fisheries management. The policy aims to ensure "....the sustainable and profitable utilisation of Australia's Commonwealth fisheries in perpetuity through the implementation of harvest strategies that maintain key commercial stocks at ecologically sustainable levels and within this context, maximise the economic returns to the Australian community." The Policy states that:

> *"Economic considerations are important in determining appropriate targets for a harvest strategy. Economic efficiency in a fishery implies that the fish stock is protected and that the net returns (profits) of fishers are maximised. This occurs when the sustainable catch or effort level for the fishery as a whole maximises profits. This point is referred to as maximum economic yield (MEY). However, economic efficiency will only be ensured if a management regime is also in place that allows for fishing costs to be minimised and fishing revenue maximised at the given MEY catch level. That is, two conditions must be met simultaneously to achieve economic efficiency in a fishery:*
>
> - *MEY catch level is set — this will account for the impact of current catches on future fish stocks, catches and fishing costs.*
> - *A management regime is in place that allows fishers to apply the appropriate level of inputs in a fishery — this will help ensure that fishing costs are minimised and fishing revenue maximised for the given MEY catch level.*
>
> *MEY depends on a combination of biological and economic factors. In particular, it depends on the relationships between harvest, stocks and recruitment and on the way in which fishing behaviour, revenue and costs relate to those factors."*

It is important to understand that the MEY concept relates to the "whole of fishery" at the fleet level, not to the profitability of individual businesses or boats. This is sometimes misunderstood by industry when they consider the use of economics in fisheries harvest strategies means intervention into their individual businesses ("we know best about profitability"). As a result, industry often states that managers should be more concerned with sustainability than economic efficiency.

This project is focused on addressing misconceptions about the use of economics in fisheries harvest strategies.

Consultation

This project was highlighted as a CRC priority during 2013. Based on the success of the 11 educational videos produced as a part of FRDC Project 2010-306 "***Empowering Industry through Improved Understanding of Stock Assessments and Harvest Strategies***", the CRC approached Fishwell Consulting to develop a project to explain the use of economics in harvest strategies.

Need

Successful adoption of fisheries harvest strategies is benefited by a good understanding of the underlying concepts. Generally, the concept of "sustainability" is well understood by all stakeholders and has been implemented in all state and

Commonwealth harvest strategies around Australia. The concept of "Maximum Economic Yield" (MEY) in fisheries harvest strategies, on the other hand, is far less well understood and as a result, is much more poorly implemented.

Despite improvements in the assessment and harvest strategy process over the last decade, there remains a level of industry frustration and misunderstanding about how this translates into beneficial management decisions. Some of this can be attributed to a lack of knowledge about assessment techniques and how these underpin a harvest strategy. A better understanding of the MEY concept amongst fishery stakeholders is required so there is better support for the inclusion of economic targets into fisheries harvest strategies.

Objectives

1. Increase the level of understanding of industry and fisheries managers on the role and benefits of fisheries economics in fisheries management.
2. Production of a short (5-8 minute) video on economics in fisheries harvest strategies.
3. Production of a Power Point presentation on the economics in fisheries in harvest strategies.

Methods

Workshops are a commonly used format for delivery of fisheries science information. Workshops have the advantage of the participants being able to interact with the presenters by asking questions, and also for the pace of information delivery to be adjusted based on the level of understanding. The main problems with this approach are the amount of time taken to deliver the information, the expense in doing so, and the small number of participants that can be involved in each workshop if it is delivered locally — at a port for example. If a larger workshop is held more centrally, it often requires fishers to travel for at least a day to attend and then return from what would be a 1-2 day workshop. This length of time away from their fishing operations is often not feasible for commercial fishers. We believed that to achieve wide-spread coverage of the fishing and seafood industry, workshops are often not the most appropriate method of education and communication.

Handbooks and brochures are another method of conveying fisheries science information. The advantages of this delivery format are that it can have high level of scientific detail, can be read at a time that is convenient to the reader, and can be re-read to reinforce understanding. The disadvantages are that some of the target audience may not like to read, especially a potentially ‘dry’ subject such as economics in harvest strategies. Further, this method of delivery relies on the audience having a level of reading ability that enables comprehension of technical writing and graphs. This is not always the case and based on past experience, reading is not a particularly popular pastime for a significant proportion of crews on commercial fishing vessels.

Video media is an appropriate method of delivering fisheries science information to many fishery stakeholder groups that do not have an extensive scientific background. Videos can be delivered via DVD or online through websites such as YouTube, Vimeo and Facebook. This means that the information is available to a very wide audience, at very little cost, and can be viewed at the audience’s leisure. From experience, we

also know that one of the most popular pastimes of commercial industry members on vessels is watching DVDs, and that many younger fishers regularly use social websites such as Facebook. Accordingly, the main method chosen for communicating the educational material was a narrated video format that used footage of fishing operations, and included interviews with "case study" fishermen. Segments with fishermen talking about fisheries economics and how it relates to their fishery assists getting the technical subject matter across to other fishery stakeholders. Further, interspersed between these segments and across the narration, footage of fishing vessels and deck operations is of visual interest.

The use of educational videos has been shown to be very effective for conveying fishery science information. During May 2013, 11 chapters of a Fisheries Stock Assessment Modelling video were uploaded to You Tube (www.youtube.com/FishwellConsulting) and have already received over 5000 views. The series also has been made available for AFMA's RAG and MAC induction workshops run in 2014 and 2015.

This project required the production of educational material conveying the importance of economics in fisheries harvest strategies using a range of different media: a PowerPoint presentation, a small brochure and a video. Although being stand alone, these MEY 'modules' relates to other outputs from the "*Empowering Industry through Improved Understanding of Stock Assessments and Harvest Strategies*" series, and hosted on that series' YouTube Channel.

Results and Discussion

The only required output from this project was the production of a video, brochure and PowerPoint presentation. These are described below

Video

A video of duration 12:53 was produced following a script drafted and reviewed by all co-investigators (Appendix 1). It was written at a level suitable for the target audience, and the video includes explanatory graphics, interviews as well as footage of commercial fishing operations. The video follows a similar style to videos produced from FRDC Project 2010-306 "*Empowering Industry through Improved Understanding of Stock Assessments and Harvest Strategies*". The video is hosted on YouTube, and can be accessed / linked as described in Table 1. This link has already achieved more than 350 views.

The video has been promoted amongst fisheries agencies and peak bodies.

Table 1. URL, embed code and QR code for video

URL	https://youtu.be/rsnXbEQz54I
Embed code	<iframe width="560" height="315" src="https://www.youtube.com/embed/rsnXbEQz54I" frameborder="0" allowfullscreen></iframe>
QR Code	

Brochure

The brochure (Appendix 2) was written by project staff and graphic design was undertaken by Charlotte Whitby. The final copy has now been completed and will be printed and distributed to fishery peak bodies, government departments, educational institutions and environmental NGOs to improve their understanding of fisheries economics

Power Point

A PowerPoint presentation was developed that closely follows the brochure, including images produced for the brochure. The PowerPoint has been submitted to the FRDC and is available for general use.

References

DAFF (2007). Commonwealth Fisheries Harvest Strategy Policy and Guidelines. Department of Agriculture, Fisheries and Forestry, Canberra.

Benefits and Adoption

The main benefit of this project is to increase the knowledge that fishery stakeholders have on the role of economics in harvest strategies. Along with videos produced for FRDC Project 2010-306 "*Empowering Industry through Improved Understanding of Stock Assessments and Harvest Strategies*", this project will leave and enduring legacy of improved understanding and knowledge of the stock assessment and harvest strategy process. It is hoped that this will improve stakeholder involvement and input into the development of harvest strategies that incorporate economic targets. This will assist in the improved management of fisheries.

Further Development

In the longer term, the material developed could be incorporated into other training packages being developed for the fishing industry and/or as a training stream under the Seafood Industry Training Package offered by the National Training Information Service.

Planned Outcomes

This project undertook and developed following project materials:

1. Video
2. Brochure
3. Power Point

The planned outcome is that that industry has more effective understanding of the role of economics in harvest strategies, which will in turn lead to improved harvest strategies and better managed fisheries. Outputs have be delivered to fishery peak bodies, government departments, educational institutions and environmental NGOs to improve their understanding of stock assessments and harvest strategies. Ultimately, this will benefit not only the end users of the research outputs (commercial and recreational fishers), but also the general public through enhanced management practices and enhanced resource sustainability.

Appendices

Appendix 1: Fisheries Economics Video Script

In the last chapter of our video series, we looked at harvest strategies with limit reference points and target reference points. Limit reference points are set to ensure stocks aren't overfished and target reference points are set as a goal for getting the most out of a fishery. But people's concepts of "getting the most out of a fishery" are different depending on who you talk to.

Not that long ago, most people thought that getting the most out of the fishery involved getting the biggest long-term tonnage, otherwise known as the maximum sustainable yield, or MSY. More recently however, people have started thinking that getting the most out of a fishery involves getting the best long-term economic return, called the maximum economic yield or MEY.

Now, MSY - Maximum Sustainable Yield - is calculated with biological information like growth, mortality and recruitment. But, to properly examine the economics of a fishery then we need to factor other things like dollar value of the catch and expenses associated with fishing like maintenance, fuel and labour. Including this financial information allows us to calculate what getting the most out of your fishery means in terms of MEY, or maximum economic yield.

In this video we're going to use the western rock lobster fishery as a case study to explore the use of economic targets in fisheries and explain the potential benefits of having an MEY target compared to an MSY target.

Up until the mid-2000s, the biological objective for the Western Rock Lobster fishery was to maintain the breeding stock at or above the levels in 1980 to ensure sustainability.

Bites from interviews.

So let's now introduce a graph to help demonstrate how different possible targets may be used in a fishery harvest strategy. The best way to explain this graph is to draw it from scratch. On this line we have fishing effort and on this line we have yield from the fishery in tonnes. So let's look at effort first. In the Western Rock Lobster Fishery, effort is measured in pot-lifts, but in other fisheries it might be for example number of hooks, number of trawls or hours fished. It's important to understand that we're not talking about an individual boat here, we're talking about the whole fishery. Now, the curve of our graph starts here and it's easy to see that if there is no fishing effort then there won't be any catch. As fishing effort increases, so does the yield until the fishery reaches a point where the yields begin to decrease because the surplus stock is being fished down. At very high levels of fishing effort, the stock is fished down to a point where there is no surplus of fish which means no yield as well. But at this point here, at the top of the curve, is where, in theory, we get MSY the maximum sustainable yield from a fishery. In practice this point is hard to pin down because of uncertainty and year-to-year variations in stock dynamics. Nevertheless, although simplistic, it's worth remembering this graph because it's fundamental to understanding fisheries harvest strategies.

In the Western Rock Lobster Fishery before 2005, MSY was the target reference point that fisheries managers were aiming for. The Western Australian State of the Fisheries

Report for 2005/06 noted that the western rock lobster stock remained close to maximum sustainable yield. But did this strategy have some inherent problems and not get the best out of the fishery?

Bites from interviews

Even though the fishery was operating with catches at about MSY, an unprecedented period of low settlement between 2006 and 2013 forced a complete change in how the Western Rock Lobster Fishery was managed. A huge effort reduction of about 70% was introduced to protect the breeding stock. In 2010, the fishery also changed from an effort-controlled fishery to a quota-controlled fishery. These changes were designed to move the fishery from an MSY target to an MEY target, maximum economic yield. To help explain what the difference is, we'll need to go back to our graph and make some changes.

The bottom line of the graph remains as effort but we need to change the vertical line here from yield in tonnes to yield in dollars. The curved line now represents revenue from the fishery – not catches. So let's go back to the part of the curve that maximizes the yield. Now that sounds like a good place to be for a fishery, where catches are highest – that means economic yield is at its best for the fishery. Right? Wrong! When you add in the economics of the cost of fishing it becomes a little more complicated.

Let's add another line representing the variable costs of fishing. Obviously the more effort, the greater the cost in fuel, repairs, bait, salaries etcetera and for simplicity we assume the relationship of costs is a straight line directly proportional to effort. If you draw this line out, the cost of fishing will eventually cross the line of revenue, at which point it starts to cost more to catch the fish than revenue raised from selling it.

All points on this graph can be biologically sustainable but only the area between the curved revenue line and the straight cost line is where there is a net positive economic return from the fishery – where revenues are greater than the costs. We want our fishery to be somewhere in this area. You can see though that there is a large range of effort levels that still deliver positive economic returns. At this end there is more effort in the fishery, smaller stock sizes and generally lower catch rates. At this end stock sizes are higher because effort and catches are lower, but economic yield is not as high as it could otherwise be with more effort - this means the fishery is being underutilised.

MEY, or maximum economic yield, is when the sustainable catch or effort level for the fishery as a whole maximises long term profits or, where the difference between total revenues from the catch and the total costs of fishing is greatest. So, on our graph the point at which there is the greatest difference is between revenue and costs is here. This is MEY. Simply put, it's the level of effort that results in the best economic returns for the whole fishery. Remember, we're not talking about individual boats here, we're talking about the fishery as a whole. Now the good news for fishers is once a fishery is at MEY – the opportunity for good profits for individual boats is optimised.

In the case of the Western Rock Lobster, fisheries managers made fundamental changes to the harvest strategy and achieved MEY for the fishery. This also made big differences to the level of profitability achieved for the boats remaining in the fishery.

However it's important to point out that these changes didn't come without a fair bit of pain felt by the fisherman.

Bites from interviews

But seven years on and the fishery has seen wholesale changes, not only to the price fisherman are getting for their catch but also the profitability of their businesses.

Bites from interviews

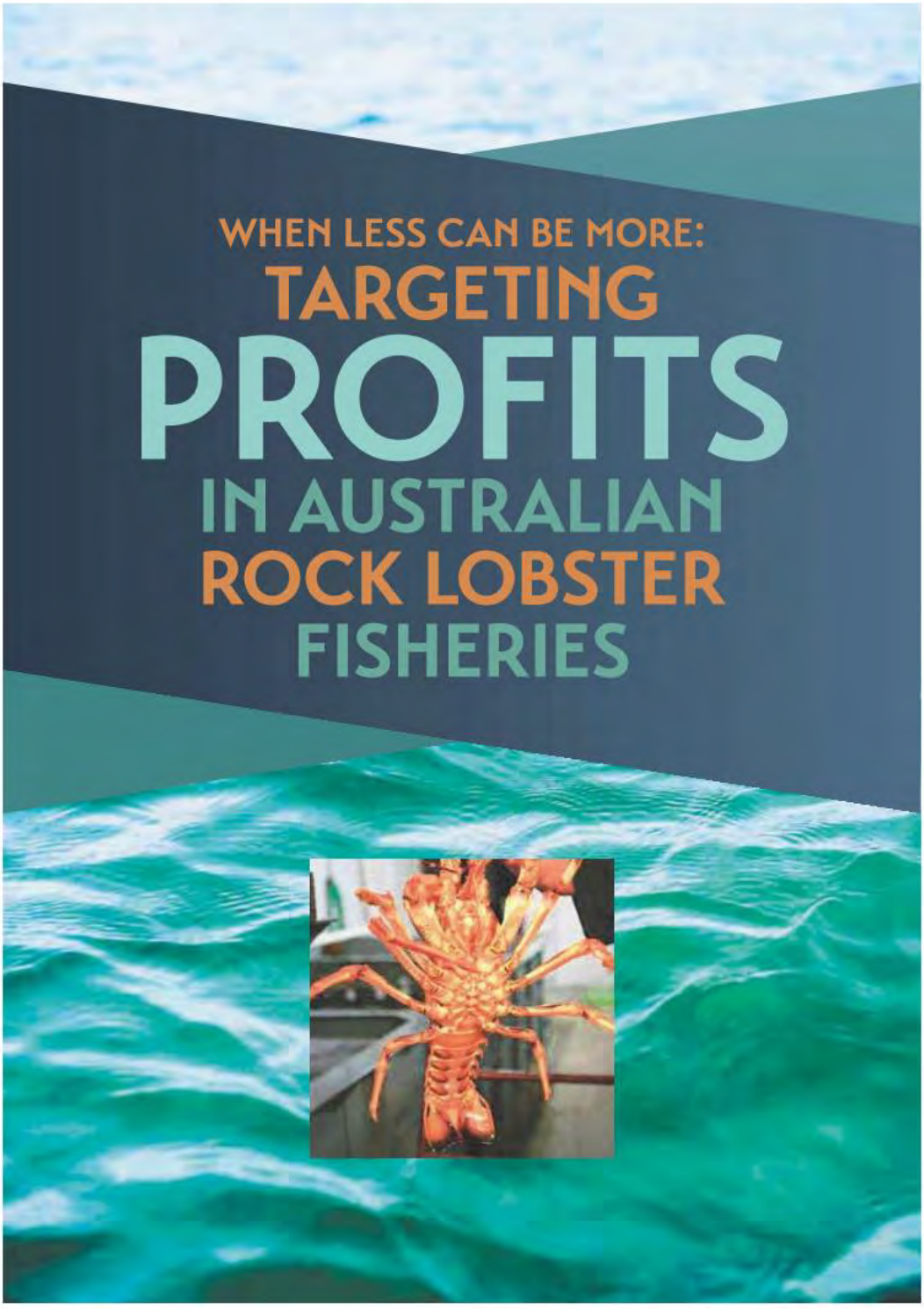
In any business, balancing costs with income is the trick to making a profit. In recent years there's been a growing shift away from fishing for tonnage towards fishing for profit. It may seem strange but in many fisheries, lower catches results in improved catch rates and therefore higher profits.

Governments in each jurisdiction have an obligation to ensure that harvests are biologically and ecologically sustainable. But once this obligation is met, they still have a range of choices on what they want from the fishery economically; and this isn't always maximum economic yield. That's because the most suitable economic targets vary from fishery to fishery. In most Australian fisheries it's appropriate to target maximum economic yield as we've seen for the western rock lobster fishery. But, if unemployment were a special concern then it would be better to target higher levels of effort and employment. Or, if the community relied on the fishery for food then maximum sustainable yield would be the best target.

In summary then, while maximum sustainable yield as a target theoretically allows more catch to be taken, it comes at the price of lower profits and less stability in the stock. Compare this with a maximum economic yield approach which not only improves the overall revenue from a fishery, but is more likely to result in a healthy fishery, with good catch rates and a more stable stock biomass.

Appendix 2: Draft Brochure

The final brochure has been forwarded to the FRDC, and each page is shown below.



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When less can be more: targeting profits in Australian rock lobster fisheries
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In submitting this report, the researcher has agreed to FRDC publishing this material in its edited form.

WHEN LESS CAN BE MORE: TARGETING PROFITS IN AUSTRALIAN ROCK LOBSTER FISHERIES

Matt Koopman, Ian Knuckey, Ian Cartwright,
Caleb Gardner and Richard McGarvey

When less can be more: targeting profits rather than quantity in Australian rock lobster fisheries

Whether we like it or not, economics is a critical part of modern fisheries management. There has been a shift away from management arrangements that try to maximise tonnage of fish caught (maximum sustainable yield – MSY), towards trying to maximise the economic returns from a fishery, or in scientist speak, to achieve maximum economic yield (MEY). This is not at the expense of fish stocks, because sustainability and increased stability of catches go hand in hand with high, long-term economic yields.

A fisherman's first reaction to the concept of MEY is often to tell fisheries bureaucrats to butt out of their commercial business affairs and leave economics to fishermen who understand the ups and downs of their own businesses. However, Government has a responsibility to maximise the economic yield of a fishery as a whole. In fact, most Australian fisheries policy relating to rock lobster fisheries makes reference to trying to improve the economic yield. Fisheries managers try to do this by controlling the stock status through decisions such as increasing or reducing Total Allowable Catches (TACs). Working within this TAC, or quota, it is still up to the individual fishing business to maximise their own profitability — this is not the role of Government.

★ COMMERCIAL FISHING IS A BUSINESS AND SHOULD CREATE WEALTH ★

In this article, we will use examples from rock lobster fisheries to explain why fishery managers do get involved in fishery economics and why this is not necessarily a bad thing for fishing businesses. Specifically, we summarise some of the economic research that has been done on rock lobster fisheries to provide options for improved economic yields from fisheries. Our hope is that this will:

- Promote discussion about improving management of rock lobster fisheries to make them more profitable;
- Improve industry's understanding of fisheries economics to increase "buy-in" of fisheries management; and,
- Push the boundaries on what gets discussed by industry, investors, and banks (move beyond – "more quota good, less quota bad").

Maximum Sustainable Yield (MSY)

Early fisheries theory from the mid-1950s established a formal relationship between fishing effort and the "surplus yield" available in fish stocks. Importantly, this modelling was supported by studies based on real life observation and experience. This relationship is described in the diagram below based on a simplified rock lobster fishery. The curve in this simple diagram represents yield (catch) in weight.

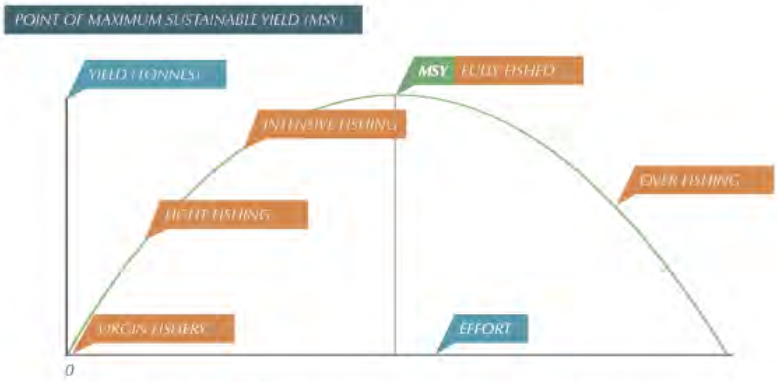

Figure 1. Diagram showing the surplus production relationship between yield from fishery (tonnes) and fishing effort. The maximum sustainable yield (MSY) is where the yield from a fishery begin to decline with increasing effort.

Prior to any fishing (a virgin fishery), the number of rock lobsters entering a fishery each year (recruitment) is roughly equal to the numbers dying of natural causes. At this time there is a very large population of rock lobsters, held back only by the ability of the environment to provide habitat, food etc. So in a virgin fishery we have no fishing, and a large, stable population. In reality, the population size changes from year to year for a variety of reasons even without fishing, particularly from different levels of recruitment, often determined by varying environmental conditions. Environmental changes will also affect rock lobster populations by affecting survival and growth.

★ ★ ★ **SURPLUS PRODUCTION** ★ ★ ★

IS THE AMOUNT OF ADDITIONAL GROWTH IN A POPULATION (FROM RECRUITMENT AND GROWTH IN SIZE) THAT RESULTS FROM FISHING. THIS OCCURS BECAUSE OF MANY REASONS INCLUDING REDUCED COMPETITION FOR FOOD AND HABITAT.

2

Looking at Figure 1, if light fishing occurs on that large population there are plenty of rock lobsters and catch (yield) increases more or less in proportion with an increase in fishing effort. Under light fishing effort, some of the rock lobsters that would have died naturally are being caught instead. To a large degree, catch (fishing mortality) is just replacing fish dying of natural causes (natural mortality) without really adding to it.

At higher fishing effort, the catch no longer increases in proportion with the effort. Fishing mortality is still being absorbed by a reduction in natural mortality. However total mortality increases and the population size is reduced. Decline in the population is dampened because food and shelter resources are freed up, which means that productivity of the rock lobster stock increases. That is, more juveniles survive and grow.

Eventually a limit is reached and higher effort does not lead to higher catch. The highest point on this curve is known as the Maximum Sustainable Yield (MSY).

If higher effort is applied, total catch will be lower because productivity is reduced. The loss in productivity occurs because of growth overfishing, which means yield from individual rock lobsters would be higher if they were allowed to grow larger. Productivity can also be reduced because the stock of breeding rock lobsters becomes depleted and recruitment starts to decline. This is called recruitment overfishing.

Higher levels of effort in this fishery can still be sustainable and stable, it's just that the overall yield is less than what it could be with lower effort. There may be advantages in being at fishing levels higher than that producing MSY, because employment and/or number of boats operating in the fishery is higher.

Most rock lobster fisheries in Australia have informally tried to target MSY in the past. So, is MSY — with the maximum sustainable catch of rock lobsters — a good place for a fishery to be? Experience in rock lobster fisheries in Australia and elsewhere has shown the answer to this question is a resounding NO, chiefly on the following grounds:

1. the actual level of catch and effort that delivers MSY is not stable through time but varies from year to year due to variations in recruitment. This means that the fishery shifts to an overfished state whenever recruitment is below average;
2. it considers only the benefits or revenue, not the costs of harvest. This means that it may not be the best outcome in terms of economic yield; and,
3. it is too sensitive to political pressure from those more interested in maximising short-term catch than profitability.

Seeking to maximise catch is important where the community relies on the fishery for food, but for luxury food like rock lobsters the objective should be to maximise profit, not catch or revenue.

There is little point in taking a large catch, only to lose most of the benefit in the costs of taking that catch (fuel, pots, bait). A smaller catch, taken at high catch rates and low costs can often result in more profit for the individual operators and a better economic yield from the fishery as a whole. Let's now look at the concept of MEY, or Maximum Economic Yield.

Maximum Economic Yield (MEY)

The economics of rock lobster fisheries is affected by much more than just the amount of fish landed and beach price. If we are going to fully understand the concept of MEY then we need to understand fishery "bioeconomics". This combines biological information on a stock's growth, mortality and recruitment with information on the dollar value of the catch and the expenses associated with fishing – like maintenance, fuel, labour etc.

Although related, it's very important to make a distinction between the use of economics to understand profitability of individual businesses and government's use of bioeconomics to responsibly manage fishery harvests so as to get the best economic yield from a fishery resource. Fortunately the following fundamental economic rule applies to both situations.

★ ★ ★ **PROFIT = REVENUE – COSTS** ★ ★ ★

At the level of the individual fishing business, fishers work hard to maximise profits by getting the best revenue from their rock lobster catch and minimising the costs associated with fishing. Business profits are maximised where the difference between the revenue from the sale of the catch and costs of fishing is the greatest. Unlike many other industries, however, the revenue and costs of fishing are not always predictable, and can fluctuate depending on the status of the stock. Relative fishing costs are a lot lower when the stock is abundant and catch rates are high, because you catch more for a given level of fishing effort. Across the whole fishery, this means less effort is needed.

Bioeconomics is not about the business-level economics of individual operators — it is used at the fishery-level to help managers and industry make informed and appropriate decisions on, say, fleet size, TACs, or size limits that maximise the economic yield from the entire fishery in the longer term. Similarly though, this occurs at the point where the difference between the revenue and costs is the greatest.

Because managers tend to talk about the value of a fishery over time, you'll often see the term Net Present Value or NPV used in bioeconomic modelling. This is a way to sum up profit over future years but assumes a dollar earned in the future won't be worth as much as one earned today.

As daunting as the term sounds, bioeconomic models can help us understand many aspects of fisheries. They are used to check the effectiveness of different management arrangements (e.g. TACs and size limits), in achieving beneficial economic returns from a fishery in line with management objectives. Bioeconomic models are commonly used to explore MEY in a fishery – let's see how they do this.

Similar to Figure 1 above, the curved line in Figure 2 represents the fishery yield in dollars rather than catch, showing the total revenue from the fishery in dollars. From zero revenue when there is a virgin stock and no fishing, total revenue increases up to a maximum point (MSY) in a fishery and then declines as effort increases.

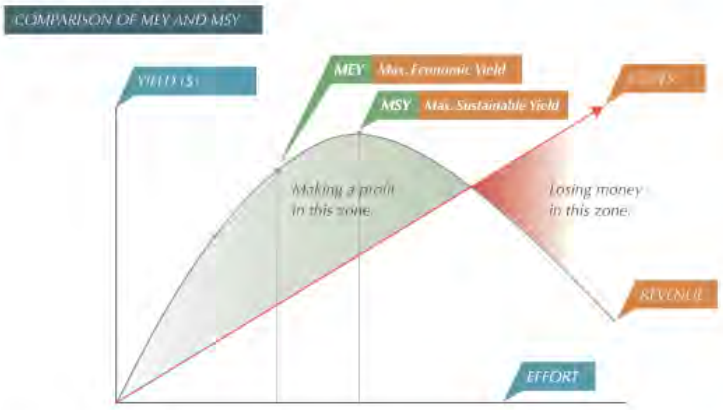

Figure 2. Diagram showing the relationship between total revenue (TR) and total costs (TC) with increasing effort and the resultant economic yield ($) from fishery. The maximum economic yield MEY occurs to the left of the maximum sustainable yield (MSY), where effort is lower and stock size is greater.

Let's add another line representing the total costs of fishing. Obviously the more effort, the greater the cost in fuel, repairs, maintenance, labour, etc. and for simplicity we assume the relationship of costs is a straight line directly proportional to effort. If you draw this line out, the total cost of fishing will eventually cross the line of revenue, at which point it starts to cost more to catch the fish than revenue raised from selling it. This is the point at which the fishery moves from a net positive economic yield (profit – in green) to a net negative economic yield (loss – in red)

All points on this graph can be biologically sustainable but only the green area between the curved revenue line and the straight cost line is where there is a net positive economic yield

from the fishery – where revenues are greater than the costs. We usually want our fishery to be somewhere in this area, but exactly where?

You can see there is a large range of effort levels that deliver positive economic returns (the area shaded in green). At the right-hand end with more effort in the fishery, there are smaller stock sizes and lower catch rates. Fisheries operating here — on the downward-sloping side of the curve —maybe have high employment and a large number of vessels but have lower overall revenue than is possible. Fisheries in this situation can also be less stable because they rely more on yearly recruitment to maintain catches. If there is a period of poor recruitment, fishers need to work harder to maintain catches, which drives the population and catch rates lower. At the left-hand end near zero fishing effort, stock sizes are higher because effort and catches are low but economic yield will not be as high as it could otherwise be with more effort — this means the fishery is being underutilised.

MEY occurs somewhere in between: where the total revenue – total costs is maximised (indicated by the arrow at MEY). You will notice the point of MEY is to the left of MSY, where there is lower fishing effort and larger stock size. Put simply, an MEY approach not only improves the overall profits from a fishery, but is more likely to result in a more stable fishery, with higher stock abundance and good catch rates. Fisheries that target MEY are more able to withstand the levels of fluctuation in recruitment that are common in rock lobster fisheries. While MSY as a target theoretically allows more catch to be taken, it occurs with lower profits and lower stability of businesses.

Information needs for bioeconomics

Bioeconomic modelling combines information on the underlying stock dynamics of a rock lobster fishery with fishing effort and the economic costs and returns of harvesting and selling the catch. So, in addition to information on a stock's population dynamics (the 'biology', including growth, mortality, recruitment, etc.), biodynamic models need information on the income received from

sale of the fish (revenue) and the money that the fishing business spends to catch the fish (costs).

Getting a handle on revenue is pretty easy. Fish receivers (or processors) record information on quantity traded, total price, unit price per kg and sometimes size and colour. From these, revenue can be calculated, adjusting for differences in size or colour.

Calculating costs is more difficult, and usually involves fleet-wide surveys of individual fishers. Survey questions asked can include capital costs such as vessel, fishing gear and leasing pots or quota, expenditure on things such as wages, fuel, licence fees and insurance, and they often include questions about employment. Surveys are usually undertaken on a representative sample of the fishing licences, and those data used to describe costs across the fishery.

MEY targets for rock lobster fisheries?

So all this may sound good in theory but does it really work? Let's first have a look at a couple of examples from Tasmania and South Australia where rock lobster fisheries have used bioeconomic modelling to conduct theoretical investigations of potential improvements in moving to MEY targets. Then we will look at the Western Australian Rock Lobster Fishery where the move to MEY has actually happened.

Tasmania[1]

A bioeconomic model of the Tasmanian Rock Lobster *(Jasus edwardsii)* Fishery was developed to compare the use of total allowable commercial catch (TACCs) under the current management approach, and what may be required to a move towards MEY.

Modelling showed that a small (1%) decrease in TACC implemented each year for a sustained period had a positive impact on stock sustainability when compared with the current TACC level of 1470 t (Figure 3). Moreover, catch rate was projected to increase, as would the overall revenue per potlift. The main conclusion from this work was that economic yield would be increased with lower levels of catch and this appeared to be fairly robust to variation in price and costs.

Current TACCs were found to be higher than that which would achieve MEY, and the industry was vulnerable to temporal changes in productivity (on the down-sloping right-hand side of MEY).

Such modelling has been useful in the debate, but to date, there has been limited acceptance that improved economic yield and asset values could come from lower catches, and this has hindered a move in this direction. Nevertheless, the results of this work have influenced management decisions and the TACC dropped from 1470 t to 1050 t between 2010 and 2013.

1 Gardner, C., Hartmann, K., Punt, A. and Jennings, S. (2015). In pursuit of maximum economic yield in an ITQ managed lobster fishery. Fisheries Research 161: 285–292

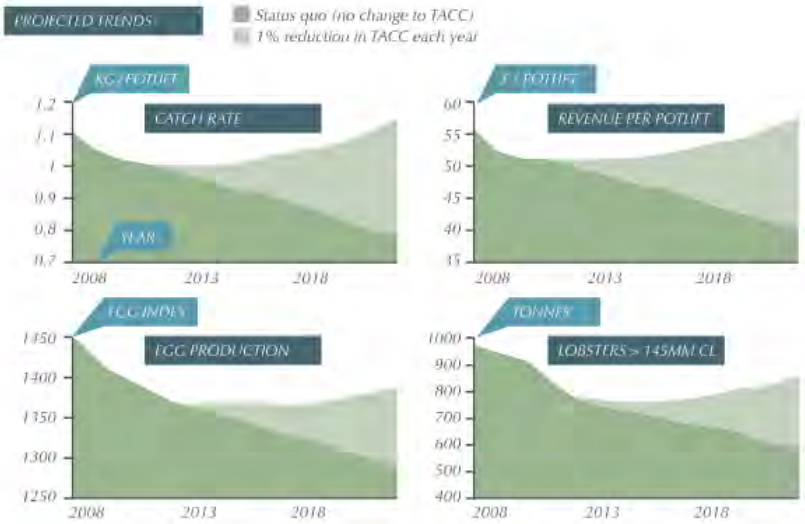

Figure 3 Projected trends in catch rate, revenue, egg production and biomass of large rock lobsters for two scenarios: status quo TACC of 1470 t and a strategy of 1% TACC reduction each year.

South Australia[2,3]

Maximising economic benefit is one of the objectives included in South Australia's state fisheries legislation. To look at achieving the best possible economic yield for the Southern Zone Rock Lobster (*Jasus edwardsii*) Fishery, a recent study compared four common fishery management policies using bioeconomic modelling, which they compared to a baseline representing current management arrangements. The four strategies were: minimum size, maximum size, constant catch quotas, and constant exploitation rate (set by yearly TACC). The performance of each strategy was measured in terms of discounted economic yield, egg production, catch, and catch stability. Here's what they found...

Minimum size

A range of minimum sizes were explored: 93.5 mm, 98.5 mm and 103.5 mm. Lowering the minimum size limit to 93.5 mm reduced the net present value and commercial catch and reduced

2 McGarvey, R., Punt, A.E., Gardner, C., Feenstra, J., Hartmann, K., Hoshino, E., Burch, P., Paterson, S., Matthews, J., Linnane, A., Rippin, L. and Marrian, J. (2014). Bioeconomic decision support tools for Southern Rock Lobster. Report to the Australian Seafood Cooperative Research Centre, Project No. 2009/714. 20. 206pp.

3 McGarvey, R., Punt, A.E., Matthews, J.M., Feenstra, J.E., Gardner, C., Burch, P., Hartmann, K., Linnane, A. (2015). Comparing creation and quota policies to increase economic yield in a lobster fishery. Canadian Journal of Fisheries and Aquatic Sciences. 72: 1293-1305.

the egg production. Increasing the size limit to 103.5 mm increased commercial catch as well as NPV and egg production. However, taking into consideration the demand for 98.5–103.5 mm rock lobsters in the Chinese market, this option was not considered favourable.

Maximum size

Keeping minimum size at 98.5 mm, maximum sizes of 145 mm, 160 mm and 175 mm were modelled. The maximum size strategy performed the worst of all strategies assessed. Adding maximum size limits did not measurably improve egg production but commercial catch and profitability were substantially reduced. Economically a maximum size limit made things worse, and no biological benefit was gained.

Constant catch quotas

Constant TACCs of 1,250 t, 1,400 t and 1,550 t were evaluated in combination with the current minimum size at 98.5 mm.

While these constant catch quotas reduced commercial catch compared to the historical average (but not compared to current Southern Zone levels), they all resulted in increased egg production and fishery profitability (as NPV). A TACC of 1,400 t resulted in the greatest NPV, while a TACC of 1,250 t resulted in the highest egg production. Constant catch quotas clearly provide higher catch stability (more consistent year-to-year catch). This is considered favourably by industry as it improved business planning including bank financing and increased efficiency of processing/tanking/exporting/transport facilities.

Constant exploitation rate (by adjusting TACC)

A harvest control rule which sets quota each year in proportion to the previous year's catch rate, while retaining the minimum size at 98.5 mm, produced the best fishery outcomes. Setting the quota to target constant exploitation rates of 30%, 40% and 50% of the stock resulted in the highest NPV, with an exploitation rate of 30% performing the best. This management arrangement resulted in the least impact on catches, and increased egg production for each of the three exploitation rates examined. While this strategy did not result in the same benefits of stability as constant catch quotas, it produced superior catch, egg production and profit, and so was clearly the best of these four strategies evaluated.

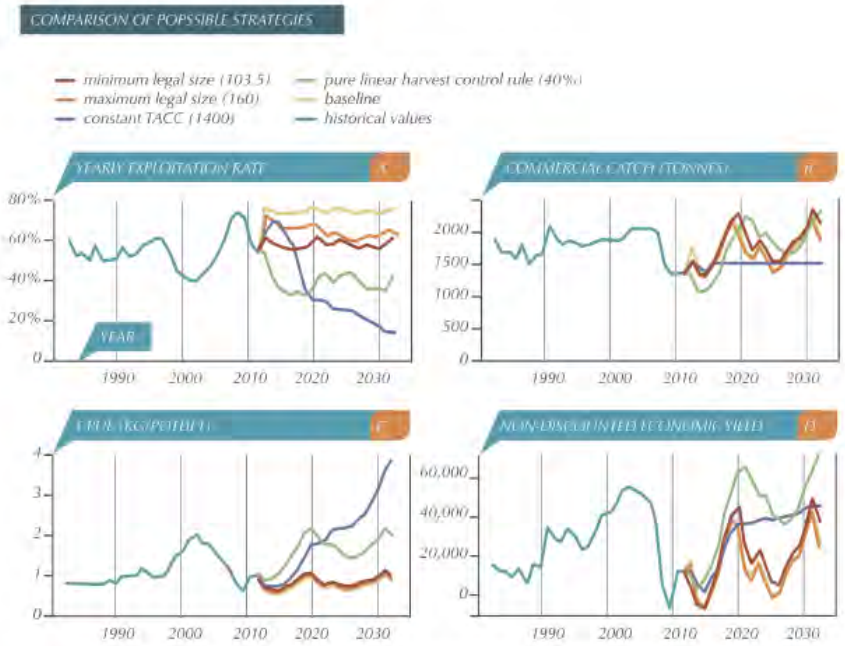

Figure 4 Yearly time series outputs for the Southern Zone Rock Lobster Fishery for five strategies averaged over 100 replicates for each projection year: (A) yearly exploitation rate, (B) egg production, (C) commercial catch (t), (D) catch-per-unit-effort (kg/pot lifts), (E) gross revenue (AUD thousands), and (D) non-discounted industry-total economic yield, NPV (AUD thousands).

Projecting these different strategies forward enables us to see how they perform in theory (Figure 4). Both the constant TACC and the constant exploitation rate perform well and promote increased egg production – particularly the former. As the stock rebuilds, however, the constant TACC strategy starts to become more conservative with decreasing exploitation rates (less than 20%, Figure 4A) and although it leads to much higher catch rates (Figure 4B) it is underutilising the stock (too far to the left in the MEY graph). Ultimately, the strategy that adopts constant exploitation rate (at about 40%) provides the best economic yield from the fishery.

So what does all this mean?

Based on bioeconomic modelling, the performance of constant exploitation rate, especially at low exploitation rate targets, demonstrates that there is considerable scope for improved performance in the South Australian Rock Lobster Fishery through management that promotes stock rebuilding leading to higher catch rates. Phasing in of management changes would reduce concern of industry in the Southern Zone Rock Lobster Fishery about the short-term impact of lower TACCs. However, results here show that any impact of lower catches on economic yield of quota owners is short lived and small in scale due to the concurrent reduction in fishing costs.

Western Australia[4,5]

The Western Rock Lobster *(Panulirus cygnus)* Fishery is the most valuable single species fishery in Australia. Prior to 2006, the Western Australian Rock Lobster Fishery measured the status of their stock against MSY; the WA State of the Fisheries Report for 2005/06 states that the Western Rock Lobster stock remained close to MSY. An unprecedented five year period of low settlement between 2006/07–2010/11, however, forced a complete change in how the Western Rock Lobster Fishery was managed (Figure 5). An approximate 70% effort reduction (compared to 2007/08) was introduced between 2008/09 and 2009/10 to protect the breeding stock during the period of low recruitment and in 2010, the fishery also moved from an effort-controlled fishery to a quota-controlled fishery with individual transferable quotas (ITQs). In addition, the fishery moved to an MEY target for the fishery.

4 Reid, C., N. Caputi, S. de Lestang, P. Stephenson (2013). Assessing the effects of moving to maximum economic yield effort level in the Western Rock Lobster Fishery of Western Australia. Marine Policy 39: 303-313.

5 Caputi, N., de Lestang, S., Reid, C., Hesp, A., How, J. and Stephenson, P. (2014). Decision-support tools for economic optimization of Western Rock Lobster Fishery. Fisheries Research Report No. 257, Department of Fisheries, Western Australia, 100p.

Figure 5. Change in the management of the WA Rock Lobster Fishery in the move to an MEY target (Figure from Simon de Lestang, Department of Fisheries - WA).

So how has the fishery performed since moving to MEY?

In only a few years, these changes resulted in a huge 40% decrease in the proportion of the stock harvested each year, and a resultant three-fold increase in egg production (Figure 6). From a biological perspective, the lower fishing effort has allowed the breeding stock and egg production to increase to now record high levels. So this was good for the stocks, but what about the fishers?

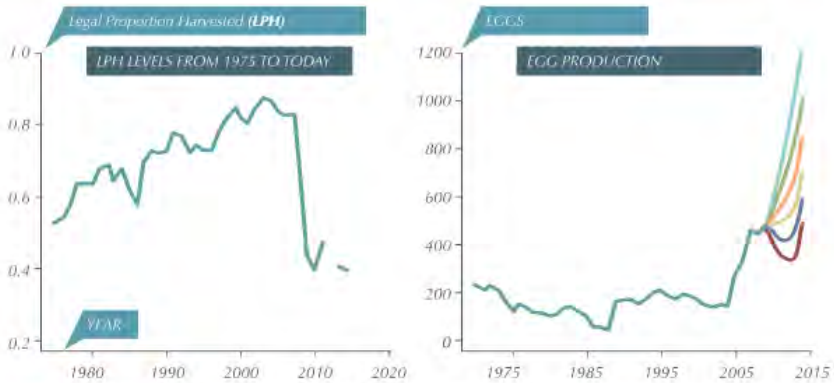

Figure 6. Diagram showing the reduction in the legal proportion harvested (LPH) and the resultant increase in egg production since move to MEY and prediction future production at different LPH levels (from Caputi et a. 2014[6]).

[6] Caputi, N., de Lestang, S., Reid, C., Hesp, A., How, J. and Stephenson, P. (2014). Decision-support tools for economic optimization of Western Rock Lobster fishery. Fisheries Research Report No. 257. Department of Fisheries, Western Australia, 100p.

Compared to 2007/08, vessel numbers had declined 36% by 2009/10, and although both catch and effort declined, CPUE has more than doubled from its long-term average of about 1.1kg/pot lift (Figure 7). The improved stock status has also enabled some of the input controls to be relaxed. Rather than being restricted to a seven-and-a-half month season, fishers can now fish all year round. This has reduced competition between commercial fishermen, reduced fishing costs and improved marketing opportunities. Beach price has also increased.

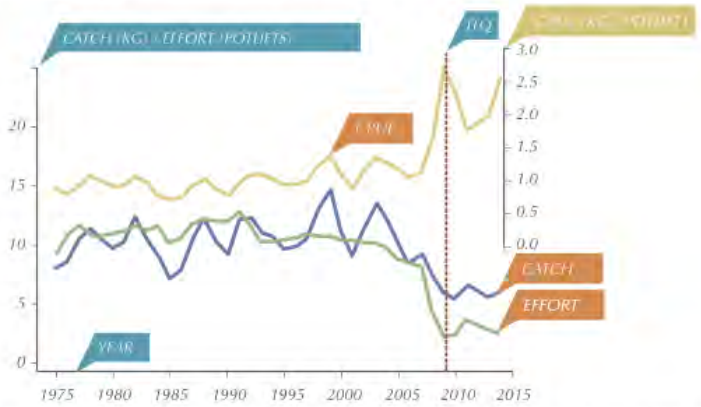

Figure 7. Diagram showing catch, effort and CPUE before and after the move to MEY and introduction of ITQs (Figure from Simon de Lestang, Department of Fisheries - WA). The vertical axis on the right hand side relates to the CPUE.

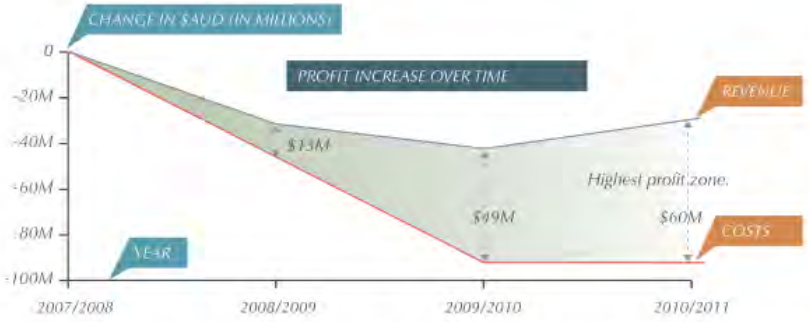

Figure 8. The resultant increase in economic yield (profit) to the fishery from change in the management in the move to an MEY target during 2007/2008 to 2010/2011. (Figure from Simon de Lestang, Department of Fisheries - WA).

The combination of all these factors has seen the economic yield from the fishery (profit) increase by AUD$13M, $49M and $60M for 2008/09, 2009/10 and 2010/11 respectively, compared to that estimated if the 2007/08 effort level had continued (Figure 8).

Why are Governments and managers interested in bioeconomics?

The simple answer is because they have to be! Each State has their own suite of legislation and policy (e.g. Fisheries Management Acts, Fisheries Management Regulations and Fishery Management Plans), and all of those relating to rock lobster fisheries include some requirement for the fisheries to be managed in a way that maximises profitability. For example, South Australia's Fisheries Management Act states that "...to protect, manage, use and develop...in a manner that achieves optimum utilisation..." while the Southern Zone Rock Lobster Harvest Strategy states "This harvest strategy aims to achieve the following three main objectives..... 3) Profitability: - decision rules that achieve stock recovery and produce higher catch rates; and higher rates lead to higher profitability."

Why should you be interested in bioeconomics and MEY?

All Australian rock lobster fisheries have been through difficult times over the last decade, particularly as a result of prolonged periods of poor recruitment. No one wants to endure the hardships and economic stress this puts on individuals, businesses and the fisheries as a whole. Whilst we may not be able to control the climate or oceanographic fluctuations that influence recruitment, we can endeavour to manage fisheries so as to minimise short-term instability associated with these fluctuations and maximise the opportunity for long-term economic yields from the fishery. There is good evidence that managing towards MEY can bring positive results to a fishery as a whole and the businesses that operate within. As more fisheries look to use bioeconomic modelling to explore the potential benefits of moving to an MEY target, industry members will need to be well informed about the underlying theory so they can play an important role in these management discussions about the future of their industry.

★ ★ ★ ★ GLOSSARY ★ ★ ★ ★

CPUE (Catch per unit effort) – catch divided by the effort used.

ITQ (Individual Transferable Quota) – a type of quota (a part of a Total Allowable Catch) allocated to individual fishermen or vessel owners and which can be sold to others

MEY (Maximum Economic Yield) – the value of the largest positive difference between total revenues and total costs of fishing (including the cost of labour and capital) with all inputs valued at their opportunity costs

MSY (Maximum Sustainable Yield) – the largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological and environmental conditions.

NPV (Net Present Value) – valuation method to value stocks of natural resources. It is obtained discounting future flows of economic benefits to the present period.

TAC (Total Allowable Catch) – is a catch limit set for a particular fishery, generally for a year or a fishing season.

TACC (Total Allowable Commercial Catch) – is a catch limit set for commercial fishers a particular fishery, generally for a year or a fishing season.

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Appendix 3: Power Point

The Power Point presentation has been forwarded to the FRDC, and images of each slide have been provided.

Slide 1

Slide 2

Why do we need to consider economics?

- Most Australian and State legislation requires economics to be considered in management of fisheries
- Amongst other things such as maximise economic returns to the community, fisheries should be managed to ensure:
  - Long term sustainability of fish stocks
  - Long term profitability

Slide 3

Maximum Sustainable Yield (MSY) explained

- Theory developed in the 1950s
- The modelling was based on real life observations and experiments
- Seeks to find the highest long term catch that can be taken from a fish stock at **sustainable** levels
- But the problems with MSY include:
  - Fish stocks fluctuate with environmental conditions
  - It does not consider the costs of fishing
  - It is sensitive to political pressure

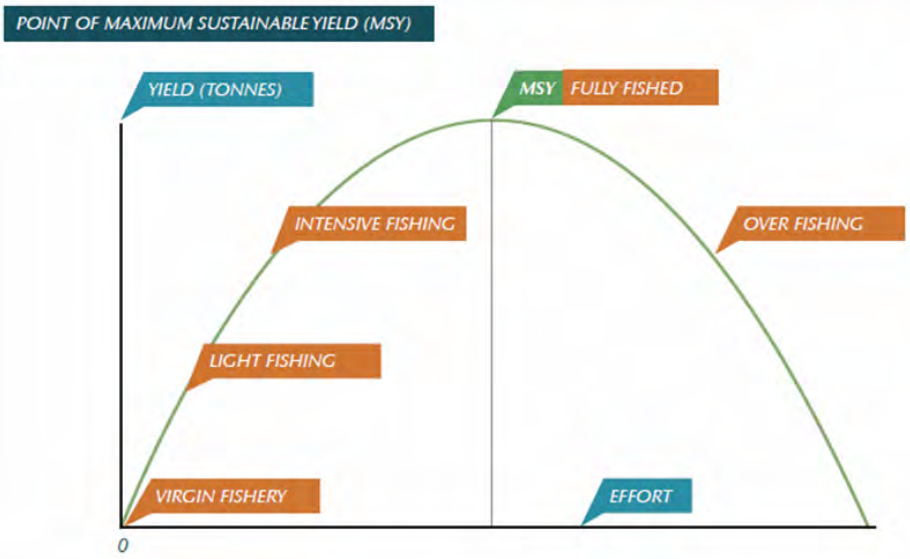
Slide 4

Maximum Sustainable Yield (MSY) explained

- Calculating MSY used the following data
  - Biological characteristics of the fish stock
    - Growth
    - Mortality
    - Recruitment
  - Revenue

Slide 5

Maximum Sustainable Yield (MSY) explained



Slide 6

Maximum Sustainable Yield (MSY) explained

- Theory developed in the 1950s
- The modelling was based on real life observations and experiments
- Seeks to find the highest long term catch that can be taken from a fish stock at **sustainable** levels
- But the problems with MSY include:
  - Fish stocks fluctuate with environmental conditions
  - It only considers revenue, not costs
  - It is sensitive to political pressure

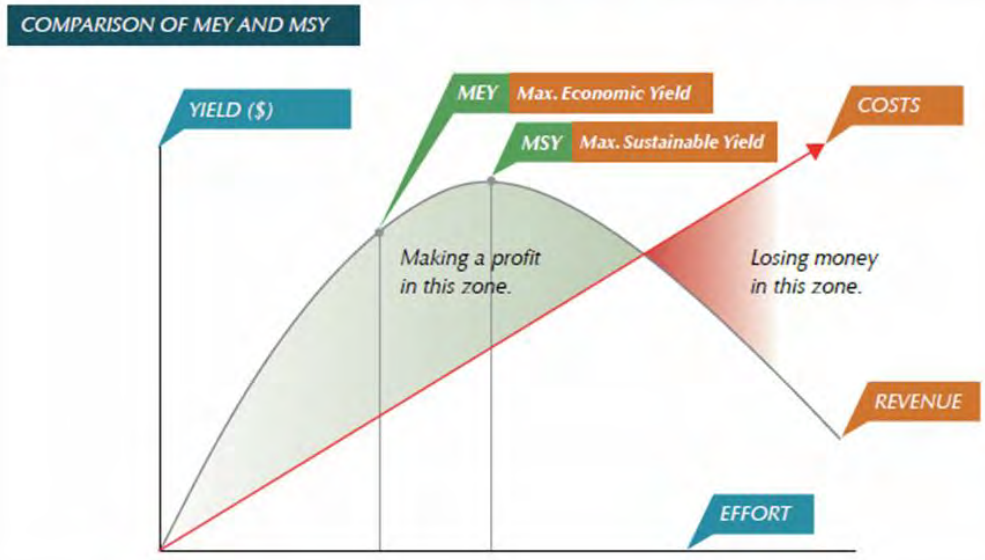
Slide 7

Maximum Economic Yield (MEY) explained

- Calculating MEY uses the data used for MSY
  - Biological characteristics of the fish stock
    - Growth
    - Mortality
    - Recruitment
  - Revenue
- **As well as**
  - Costs
  - Catch and effort

Slide 8

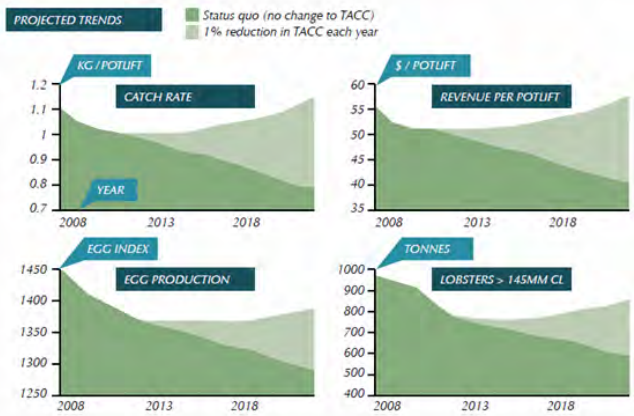
Maximum Economic Yield (MEY) explained



Slide 9

Example – Tasmanian Rock Lobster Fishery

- The project explored management options for moving towards MEY, and found that
- Compared to the current TACC, small annual decreases would
  - increase egg production
  - increase catch rates
  - Increase revenue per pot / lift

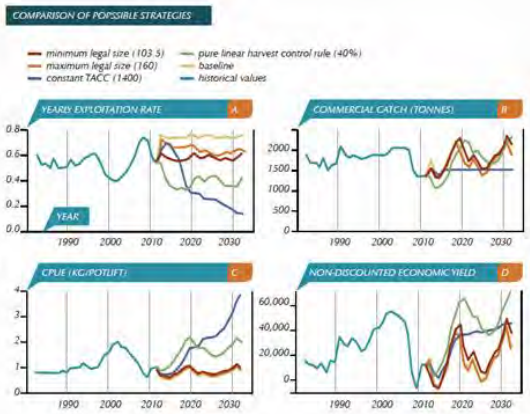


Gardner, C., Hartmann, K., Punt, A. and Jennings, S. (2015). In pursuit of maximum economic yield in an ITQ managed lobster fishery. Fisheries Research 161: 285–292.

Slide 10

Example – SZ Rock Lobster Fishery

- The project explored management options for maximising economic yield
- Compared to the current management arrangements,
  - Decreasing the MLS reduced NPV, catch and egg production
  - Increasing MLS did the but was not practical in terms of market demand
  - Adding a max size limit reduced profitability for no sustainability benefit
  - Constant TACCs increased egg production and profitability
  - Constant exploitation rate at resulted in the highest NVP, increased egg production with the lowest impact on catch

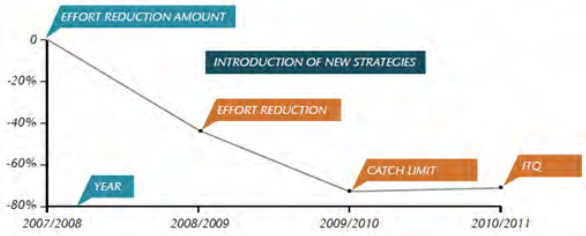


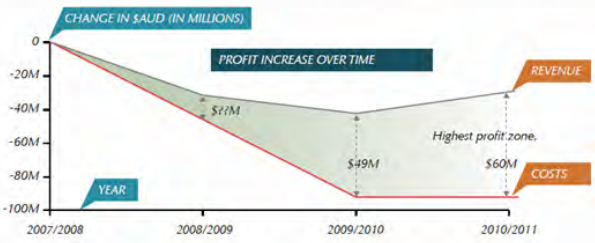
McGarvey, R., Punt, A.E., Gardner, C., Feenstra, J., Hartmann, K., Hoshino, E., Burch, P., Paterson, S., Matthews, J., Linnane, A., Rippin, L. and Morison, J. (2014). Bioeconomic decision support tools for Southern Rock Lobster. Report to the Australian Seafood Cooperative Research Centre. Project No. 2009/714.20. 206pp.

Slide 11

Example – WA Rock Lobster Fishery

- WA changed management arrangements to move towards MEY
- These changes have led to
  - increased revenue
  - decreased costs
  - greatly increased profits





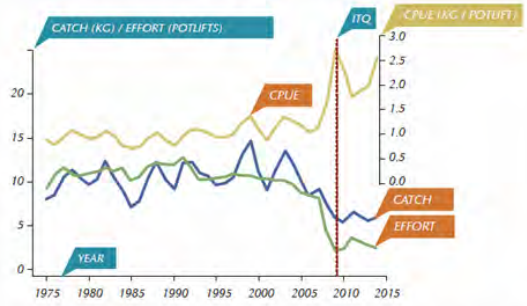
Reid, C., N. Caputi, S. de Lestang, P. Stephenson (2013). Assessing the effects of moving to maximum economic yield effort level in the western rock lobster fishery of Western Australia. Marine Policy 39: 303-313.

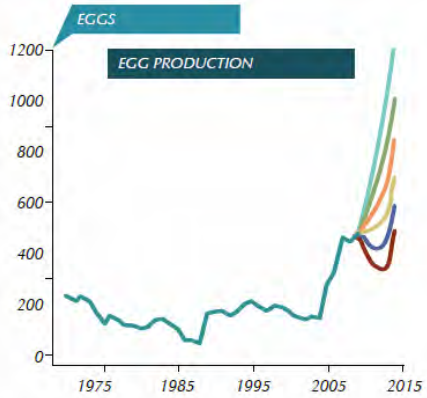
Caputi, N., de Lestang, S., Reid, C., Hesp, A., How, J. and Stephenson, P. (2014). Decision-support tools for economic optimization of Western Rock Lobster fishery. Fisheries Research Report No. 257, Department of Fisheries, Western Australia, 100p.

Slide 12

Example – WA Rock Lobster Fishery

- WA changed management arrangements to move towards MEY
- These changes have led to
  - More than doubling of CPUE
  - Increased egg production





Reid, C., N. Caputi, S. de Lestang, P. Stephenson (2013). Assessing the effects of moving to maximum economic yield effort level in the western rock lobster fishery of W Australia. Marine Policy 39: 303-313.

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Slide 13

Summary

- It is legislated that economics are considered in fisheries management
- MSY aims for the highest long term sustainable catch, but has the problems of
  - Fish stocks fluctuate with environmental conditions
  - It does not consider the costs of fishing
  - It is sensitive to political pressure
- MEY aims for the highest long term profits, while ensuring sustainability
- MEY requires bioeconomic modelling that uses a range of data including the costs of fishing
- Examples shown have demonstrated benefits of managing rock lobster fisheries towards MEY