FISHERIES MANAGEMENT

economic efficiency and the concept of 'maximum economic yield'

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• Given the problems with open access resources, as well as the effectiveness of modern fishing technology, there are few fisheries, if any, that will not be both overexploited and unprofitable unless they are managed effectively. For a fishery to be economically efficient requires that management targets be set correctly, enforced effectively and delivered in a least cost and incentive compatible manner.

• An efficient outcome is important not only because it protects fish stocks and guarantees sustainability, but also because it assures that resources will be allocated to the fishery correctly and in a way that maximises the returns from fishing. Inefficient fisheries are plagued by low profits and excessive boat capital or fishing capacity, with the all too familiar outcome of 'too many boats chasing too few fish'.

The traditional 'command and control' approaches to fisheries management — ones that focus on input restrictions and total catch limits — fail to provide the incentives for those who fish to do so efficiently and in a manner that gives industry a long term stake in the future of the fishery. These approaches often result in considerable effort creep and excessive and wasteful competition, with both inappropriate levels and combinations of inputs used to catch fish. Maximising economic yield requires not only setting catch and effort levels appropriately, it also requires that industry has an effective property right to the harvest, one that removes the incentive for a wasteful and inefficient 'race to fish'. For most fisheries, a system of individual transferable quota (ITQ) is the best instrument to ensure this outcome.

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Economic efficiency in a fishery

From the economist's point of view, the definition of economic efficiency in a fishery is straightforward. Concentrating on sustainable yields alone, economic efficiency occurs when the sustainable catch or effort level for the fishery as a whole maximises profits, or creates the largest difference between total revenues and the total costs of fishing. This point is referred to as 'maximum economic yield' (MEY). For profits to be maximised it must also be the case that the fishery applies a level of boat capital and other resources in combinations that minimise the costs of harvest at the MEY catch level. The fishery, in other words, cannot be overcapitalized and vessels must use the right combinations of such inputs as gear, engine power, fuel, hull size, and crew to minimise the cost of a given harvest.

There are several things to note about MEY at the outset. First, for most practical discount rates and costs, MEY will imply that the equilibrium stock of fish is larger than that associated with 'maximum sustainable yield' (MSY), as shown in the following section. In this sense the economic objective of MEY is more 'conservationist' than MSY and should in principle help

protect the fishery from unforseen or negative environmental shocks that may diminish the fish population.

Second, the catch and effort levels associated with MEY will vary, as will profits, with a change in the price of fish or the cost of fishing. This is as it should be. If the price of fish increases it pays to exploit the fishery more intensively, albeit at yields still less than MSY. If the cost of fishing rises, it is preferable to have larger stocks of fish and thus less effort and catch.

Finally, as long as the cost of fishing increases with days fished, as it generally will, MEY as a target will always be preferred to MSY and of course to any catch or effort level that corresponds to stocks that are smaller than those associated with MSY. The reason is simple. Regardless of what happens to prices and costs, targeting catch and effort at MEY will always ensure that profits are maximised. Profits may be relatively low when the price of fish is low and the cost of fishing is high, but profits will still be maximised. With a biological target of MSY alone, however, it is quite possible that profits will be very small or even zero. The fishery would thus be sustainable at MSY but not commercial, much less efficient. A target where profits from fishing are zero cannot be a good target.

Illustrating MEY

The management structure, stock level and nature and extent of fishing effort that generates 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 behavior, revenue and costs relate to those factors. A simplified representation of these relationships is given in figure A, where it is assumed that there is no uncertainty about the state of nature (more complete descriptions of bioeconomic models can be found in Grafton et al. 2004 and Hannesson 1993).

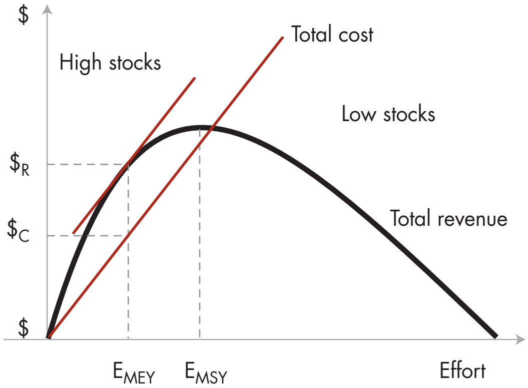
Figure A illustrates a typical production-surplus model for the fishery as a whole, expressed in terms of the relevant economic relationships. The vertical axis is simply dollar amounts and the horizontal measures effort as nominal days fished. The total revenue curve is drawn from a biological stock–recruitment relationship, translated into effort units, showing the relationship between effort and yield in dollar amounts. The larger is effort the smaller is stock size. Every point along this curve represents an effort and yield combination that is sustainable, with effort at MSY generating the largest total revenue. The total cost curve is taken as the total cost of fishing, assumed to be increasing and linear in effort, for convenience.

MEY in figure A occurs at the effort level E_{MEY} and corresponding value of catch $\$_R$ that creates the largest difference between the total revenue and total cost of fishing, thus maximising profits, given by the difference between $\$_R$ and $\$_C$. The value of E_{MEY} will change given a change in the price of fish, which shifts the total revenue curve up or down, or the cost of fishing, which rotates the total cost curve.

Given prices and costs, figure A illustrates a point made above, namely that targeting MSY will in this case generate very small profits. With a small increase in the cost of fishing, these could easily go to zero — if so, this would replicate a common property or open access equilibrium even though a management regime was in place and operating.

Note as well that a profit maximising movement away from effort at MSY toward effort at

A Maximum economic yield



Maximum economic yield (MEY) is the difference between the dollar amounts of revenue and costs at the optimal effort level, or $\$_R$ less $\$_C$. Note that MEY occurs at effort levels less than effort at maximum sustainable yield and thus at stock levels that are larger than those associated with MSY.

MEY implies a smaller value of harvest. This is often the case with overexploited fisheries — maximising profits requires less effort and smaller catches. The reason of course is that decreases in effort, which also increases the stock of fish in the future, decrease the cost of fishing more than the corresponding fall in revenue.

Nothing has been said until now about boat numbers. Indeed, the graph basically assumes that all boats are the same and there is a rough correspondence between boats and nominal days fished. In this context it is natural to assume that a move from MSY to MEY would imply a decrease in boat numbers, with catch per unit of boat increasing. It is also the nature of an optimal result that those that lose from a reduction in boat numbers can be more than compensated for by the increased profits that MEY generates, at least in principle. In any case, it is easy to see that efficiency requires that at MEY the measure of effort corresponds with a total boat capital in the fishery that is just sufficient to obtain the required catch at minimum cost. Thousands of boats each fishing a day could generate E_{MEY} but clearly that excess capacity would be inefficient.

Why MEY?

It has already been shown that MEY generates maximum profits and that this outcome is guaranteed regardless of the price of fish or the cost of fishing. Also, MEY is ‘conservationist’ in the sense that stocks will be larger than at MSY, and this in itself can confer enormous benefits to the fishery and its ecosystem. It would also protect the fishery against large negative shocks to the fish population, since larger stock levels generally imply greater resilience in the face of these shocks.

But there is another, equally compelling, reason for pursuing MEY: resource allocation. Effort levels larger than E_{MEY} would imply more boats, days at sea, gear, crew, bait and all of the other inputs used in fishing — resources that could be used instead in alternative employment. This is what economists mean by efficiency in general terms — for the economy as a whole.

If too many resources are being expended in fishing, too few are being used elsewhere. Moreover, as long as the right instruments to facilitate adjustment are in place — instruments that allow for trade in secure and specific property rights, such as the right to a share of harvest — it follows that decreasing the size of an overexploited fishery will make no one worse off and many better off by compensating those that leave the fishery for their lost income, while providing more profit for those that remain in the fishery. That is the nature of an optimal position given by MEY.

Attempts to extend resource use and particularly employment well beyond MEY are common, and often disastrous. Experience in Canada’s Atlantic fisheries provides a striking example. Subsidies provided by the Canadian Government — with a specific mandate to maximise employment levels in the industry — greatly extended the amount of resources applied to these fisheries. Indeed, even as early as 1970 it was ‘estimated that Canada’s commercial catch in 1970 could be harvested by 40 per cent of the boats, half as much gear and half the number of fishers’ (*Atlantic Groundfish Fisheries* 1997, pp. 14–15).

This is wasteful in itself, but dwindling stocks and the eventual collapse of the Atlantic fisheries — in large part caused by overfishing — even further increased the government’s burden to maintain incomes. In 1990, for example self-employed fishers received $1.60 in unemployment insurance benefits for every dollar earned in the fishery, and the ‘adjustment programs’ associated with the collapse of the fisheries cost the Canadian taxpayers over C$3 billion in the 1990s alone (*Atlantic Groundfish Fisheries* 1997, pp. 14–22).

What is wrong with input controls?

For management of a fishery to be effective in the sense that catch and stocks are maintained at desired levels, there must be either direct or indirect control over catches. Management through output controls involves explicit catch targets and direct enforcement of those targets. Management through input controls also involves some implied catch target. The fact that the catch target is sometimes only vaguely defined is one

of the reasons that input management regimes are often not successful.

The real problem, however, is the inability of input controls to control effort in the first place. The moment control of a particular input becomes the policy instrument, operators have an incentive to substitute other inputs in a way that will change the relationship between effort and catch. As well, technological advance and improvements in knowledge provide other background reasons for the relationship to change, constantly.

A manager relying on input controls is in constant competition with the imagination, energy and inventiveness of each operator in the fishery and the full technological backup of a modern economy. Effort creep is inevitable. In terms of figure A, attempting to target E_{MEY} can only be successful in the very short run, with effort creep moving the fishery to the right and thus dissipating profits, or decreasing the distance between total costs and revenues.

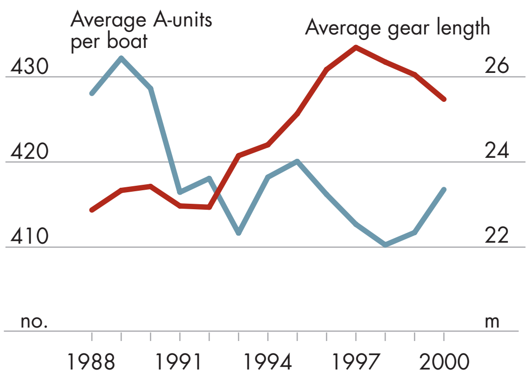
More important to the general lack of success of input management regimes are two characteristics of the incentives that they provide for operators in the fisheries. First, as mentioned, controls on one or more inputs provide an immediate incentive for operators to substitute uncontrolled inputs. Second, input control regimes provide no sense of ownership or stewardship of the fisheries resource. There are no guarantees in any input control management regime except the right of access to the fishery under certain guidelines.

Operators are encouraged by these rules to compete for catch within those guidelines, and if one operator refuses to expand effort, while others do, that operator will be worse off. Unfortunately, if all operators increase effort, all are made worse off through a fall in profits and the fishery remains overexploited — the proverbial 'tragedy of the commons'. The management response in this environment is to continuously and repeatedly find ways to cut effort (for example, gear reductions, area and seasonal closures, vessel buyback schemes, etc.), 'winding the fishery down' over time to a small number of boats or days fished, all making zero (or near zero) profits.

All of this can be nicely illustrated by a look at the Australian northern prawn fishery, providing a good example of how input controls and the resulting 'race to catch' can generate very inefficient outcomes. Over the past thirty years the fishery has been managed by a series of input controls, including seasonal closures, a move from quad to twin nets, engine power and hull limits and, most recently, gear reductions and restrictions. In all cases the limits to fishing power have been temporary at best. Indeed, A-unit (a rough measure of hull capacity and engine power) limits in place in the 1990s resulted in a clear substitution toward unregulated inputs, specifically gear. This substitution is illustrated in figure B, where average headrope gear length clearly increased throughout most the 1990s, while A-units fell.

The implication of this countermovement in A-units and gear is twofold. First, restricting A-units in fact did not control effort, since boats simply increased effort by using other inputs, including gear, more intensively. Second, the forced change in input combinations, inducing boat owners to use different proportions of gear to A-units resulted in considerable loss in boat efficiency throughout the fishery (Kompas and Che 2002). In the banana prawn section of this fishery, technical efficiency for the fleet as a whole fell from 75 per cent in 1994 to 68 per cent in 2000 (Kompas, Che and Grafton 2004). For individual operators in the fishery, the aggregate response to input restrictions thus led to

B Input substitution in the northern prawn fishery



much lower profits than would otherwise have been realised.

Each of the changes made in the management regime in the northern prawn fishery — seasonal and area closures, A-unit restrictions and most recently gear reductions — was made in recognition that the system it replaced had failed to constrain effective effort and the inevitable effort creep sufficiently to protect prawn stocks. Where effective effort was reduced by management change, the primary reduction was short lived.

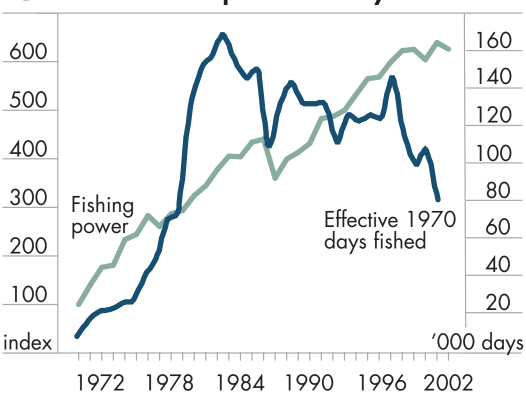
This outcome, and one of the primary reasons for it, is illustrated in figure C. Fishing power, measured as the average catching ability of a boat in a day's fishing (compared with a 1970 base — the figures used are those denoted 'basic high' by CSIRO, see Dichmont et al. 2003) has risen rapidly and consistently over time. The rise in fishing power is the result of continuous improvements in technology, input combinations and knowledge.

The acquisition of improved scientific knowledge of the fishery, along with the observation of declining catches has made it increasingly clear over the past few years that prawn stocks are not being conserved and catches and effort are not being controlled.

Although the combination of recent policy changes appears to have temporarily slowed the increase in fishing power as well as contributing to a rapid fall in total days fished, experience suggests that this will only be temporary. It took only four years for effort creep to overcome the initial fall in fishing power in response to the imposed move from quad to twin gear in 1987. The recent removal of A-unit restrictions in favor of gear reductions will logically imply, given the race to fish incentive, that boat owners will now increase the size of their vessels and engine power, spurring more and deeper compensatory cuts in gear (or some other input) in the future. Inevitably the fishery 'winds down'.

Total days fished in 2002 were already 55 per cent of the 1998 level and far below the fishery peak in days in 1983. Recent estimates show that MEY in the tiger prawn component of the fisheries is roughly 60 per cent and 30 per cent below actual days for 2000 and 2001, respectively, and about 28 per cent below actual days in the 2003 fishery. In other words, even the recent shortening of the season and further large reductions in gear units have not been sufficient to ensure economic efficiency or MEY (Rose and Kompas 2004).

C Fishing power and effective effort in the northern prawn fishery



Implementing MEY

If targeting E_{MEY} in figure A with input controls to obtain MEY is not effective or even desirable, the alternative is to target catch at (for example) the value $\$_R$. It is important to recognise, however, that aggregate catch controls can be just as ineffective as input controls, resulting in 'race to fish' behavior. Even if the total amount of catch is fixed, there is still an incentive for boat owners to overinvest in fishing capacity in order to obtain a larger share of the catch, again moving the fishery past E_{MEY}.

With effort creep an inevitable outcome of input controls, in any circumstance, economists thus argue for catch controls combined with an ITQ system to obtain or implement MEY. ITQs confer an individual, transferable, harvesting right so that each vessel is guaranteed a share of the catch. The immediate impact of this, of course, is to remove any 'race to fish' incentive (except where fishing results in stock depletion over the course of the season, implying that even though there is a catch entitlement it will be less costly to catch 'earlier' in the season when stocks are more abundant, or ahead of other

vessels. This problem is usually addressed by setting seasonal closures correctly or through quota dated by period — for example, weekly — with a market for trade across periods.)

Where there is no incentive to race to fish, there is no reason for effort to increase beyond E_{MEY}, and MEY can be effectively targeted. The regulator simply needs to set total allowable catch (TAC) correctly.

ITQs have been in place and have worked well for decades in fisheries throughout the world, including New Zealand, Iceland, the United States, Australia and Canada (Hannesson 2004). These schemes have generally established, as in the British Columbia halibut fishery, significant gains, not just in cost savings but also in enhanced revenues (Grafton, Squires and Fox 2000).

Along with creating effective property rights to fish, ITQs confer a number of other related benefits. First, since these rights are tradable, market forces will generally distribute quota among fishers that value the right most highly. Vessels that have lower marginal costs of fishing will thus be willing to pay more for quota, with the resulting transfer of quota from high to low marginal cost producers increasing economic efficiency overall — essentially fishing inputs are distributed to those who use them best.

In other cases, quota trade allows vessels to compensate for catches that are larger or smaller than planned or prior quota holdings. These efficiency gains (or what amount to cost reductions) can be substantial, even in fisheries where the TAC is not binding in aggregate. In the Australian south east trawl fishery, for example, where TAC undoubtedly does not correspond to MEY (Gooday 2004), the cost savings from quota trades are estimated to be 1.8–2.1 cents a kilogram for every 1 per cent increase in the volume of quota traded (Kompas and Che 2005).

Second, instead of investing in boat capacity to catch fish before others do, with a guaranteed harvesting right, boat owners can instead concentrate on investments that lower the per unit costs of fishing. This is a major benefit. With input controls, technological change — new boats, a better engine, more efficient gear, try nets, GPS, etc — is harmful in the sense that the resulting effort creep through increased fishing power lowers fishery profits and endangers stocks. In some cases, input restrictions are in fact designed to prevent the very adoption of such new technologies, that under other circumstances may be beneficial or efficiency enhancing, simply to control effort.

With output controls and ITQs alternatively, boat specific technological change is good, in that it lowers the costs of fishing and increases profits, with no effect on stocks or the cost of fishing of any other vessel in the fleet that does not yet adopt the new technology.

A third benefit of ITQs is that a good number of area and seasonal closures, common to input controlled fisheries, can be done away with. Spawning stocks must naturally be protected and marine reserves can almost always be justified even on economic grounds (Grafton, Kompas and Lindenmayer 2005), but area and seasonal closures used to simply limit effort are unnecessary under an ITQ system and often economically harmful in any case. By eliminating these controls, vessels can fish when the

Box 1: Impact of uncertainty

Setting effort creep aside, it should be noted that in a deterministic world (with no uncertainty) there would be no difference in outcomes between a catch or effort control, as long as the correspondence between input restrictions and effort levels is known exactly and is perfectly enforceable. With uncertainty, and again setting effort creep aside, in cases where there is more variance in the stock–recruitment relationship than in catch per unit of effort (CPUE), effort controls will be preferred. If there is more variance in CPUE relative to the stock–recruitment relationship, then output or catch controls will dominate, generating less variance in profits. For the tiger prawn component of the northern prawn fishery, the latter is the case — output controls are the preferred instrument (Kompas and Che 2004). A clear evaluation of all of the specific, or detailed, alternative fishery management instruments is contained in Gooday (2004).

weather permits and perhaps more importantly match the harvest throughout the year to market conditions, generating the highest price for their catch. In general, unlike with input restrictions, output controls and ITQs allow fishers to choose the right mix of inputs, and the time and manner to fish — all of which is cost reducing and efficient.

A final benefit of ITQs is that they allow for autonomous adjustment of the fishing fleet, with operators voluntarily able to 'cash out' by selling their quota to more profitable vessels. Indeed, if implemented correctly, an output control and ITQ system that targets MEY will generate the largest possible (marketable) asset value for those who have the right to fish, reflected in a high price for each unit of quota. Fishers are thus compensated for exiting the fishery, without the need for government intervention. This is in stark contrast to input controlled and overcapitalised fisheries where fishers lobby heavily for government vessel-buyback schemes, which are costly and often are only temporarily effective at reducing capacity.

For catch controls and ITQs to be successful there must be adequate monitoring and enforcement. This too can be costly, although there is no necessary reason for this cost to be a government responsibility. Under an ITQ system, fishers are keen to protect their secure property rights and it is not uncommon for monitoring to be at least partially funded by industry (Grafton et al. 2005). Even when government pays for monitoring and enforcement, this cost is likely to be comparable to the cost of monitoring and enforcing effort controls, not to mention the cost of any resulting effort creep that goes with input restrictions.

Similar arguments can be made about problems with highgrading and variations in stock abundance. Highgrading will most likely occur in long lived or fast growing species where the price differential between high and low grade fish is relatively large. With highgrading, a key difference between input and output controls is in the relationship between the policy instrument and the policy objective. For output controls, the possibility of highgrading means that the policy instrument (TAC) may not always match the policy objective (a given level of mortality from fishing). However, highgrading occurs in only some circumstances. Those circumstances are often predictable. As well, provided that highgrading can be estimated, the TAC can be matched with desired mortality. Unless the relationship between fishing costs and the price differential between grades changes substantially, the match will be valid over time.

There can be no doubt that waste occurs through highgrading, but that is simply a cost of management to be assessed against the other costs of management, as well as the benefits — and compared to the costs and benefits of other management instruments. More importantly, the level of highgrading enters the management decision once only. Since the incentive to highgrade is a function of the cost of fishing and the price differential between grades, it is not something that increases over time in a way that erodes the practical meaning of a catch quota, or in the way in which effort creep subverts input controls (Rose and Kompas 2004).

When considering variations in stock abundance, the traditional arguments against catch controls (and with it ITQs) are clear. With output controls, managers face a problem in setting the TAC when abundance varies between seasons and is unknown at the beginning of the season. By setting the TAC too high the manager runs the risk that fishing pressure on stocks will be excessive if a low abundance season occurs. By setting the TAC more conservatively, the manager guarantees the loss of potential profits if the season is one of high abundance. Indeed, not only is the problem well recognised, it is often cited as a primary reason for preferring input controls.

What is not so well recognised, however, is that essentially the same problem affects the setting of input controls. To set effort at the optimal level, the manager needs information on abundance, catch per unit effort, the value of catch and the cost of effort. Setting input controls too tightly leads to loss of potential profits in seasons of high abundance. Setting input controls too generously leads to excessive investment and effort and excessive catch. The long term consequences are pressure on future stocks and dissipation of potential profit.

In principle, the type of information needed to make an efficient choice using input controls does not vary much from that needed to make the choice using output controls. There is really no argument for input controls on this basis. Careful assessments of stock abundance, including where needed, fishery independent surveys and pre-season and in-season sampling, are mandatory under any management regime. If the cost of obtaining this information does vary under different regimes, or with different management instruments, a case has to be made in terms of a comparison of these costs, against all the other costs and benefits of alternative management systems.

Concluding remarks

Economic efficiency in a fishery, or pursuing MEY, is important. It not only helps protect the fish population, by ensuring that stock levels are larger than those associated with the traditional MSY target, it also guarantees that resources will be allocated to the fishery correctly and in a manner that maximises profit. Management regimes that attempt to extend the amount of resources devoted to the fishery beyond MEY only generate a system with excess boat capital and lower returns from fishing.

In many cases — especially those where input restrictions fail to prevent effort creep — the fishery simply 'winds down' to a state where total fishing days are severely limited and asset values and profits are low, with industry repeatedly calling for government assistance or some sort of vessel buyback scheme to restore profitability.

Implementing MEY requires that a system of effective property rights to harvest be established. Aggregate input or output controls alone are not sufficient to prevent a 'race to fish'. Given the inevitable problem with effort creep in input controlled fisheries, ITQs combined with a TAC set by management to target MEY is the best option for most fisheries. With a secure property right to catch, there is no longer a 'race to fish' incentive, since catch is assured, and thus no tendency toward overcapitalisation in the fishery.

Under such a system, technological change lowers the cost of fishing, rather than endangering stocks through increased fishing power. In addition, by providing a secure and easily transferable property right, ITQs result in increased capital values to fishing entitlements. Quota passes from high to low marginal cost producers, increasing efficiency, and maximising fishery profit generates the largest possible asset value for quota holders. Lowering the TAC when conditions warrant also results in relatively seamless and autonomous fishery adjustment through the exchange of quota holdings, generally passed to more efficient vessels that can afford to pay relatively more for each unit of quota.

In some cases, ITQs can be more costly to administer and enforce than other schemes and highgrading will always be a concern. However, the establishment of private property rights with ITQs, and the desire to protect them, also generates incentives for self policing and conservation. The cost of an ITQ system must also be compared with the costs associated with alternative management regimes. The cost of effort creep under an input-restricted management regime (in addition to the cost of monitoring and enforcement), for example, can be far more excessive than the cost of any comparable rights based fishery.

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Implementation of Effective Fisheries Management

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Abstract

For many people fisheries management seemingly comprises a set of actions that are akin to the administration of an almost impossibly complex bioeconomic system, almost always in a data poor environment. At its base level, this mainly features the issuing of (usually annual) fishing entitlements, annual setting of catch or effort limits sometimes based on sufficient scientific evidence and occasional monitoring against some form(s) of performance indicator. It also includes the organisation of forums for consultation where management performance is usually debated in the context of recent history and the short term future. Add to this an overlay of almost constant political lobbying intended to externally influence the outputs of decision-making and the casual observer could well be pardoned for giving the whole business a wide berth and focussing solely on consumption of the industry's products. Yet, inexorably, a much more sophisticated fisheries stakeholder debate is emerging in Australia. This stems from the need for all participants to more effectively deal with, on the one side, the oft-expressed frustration of fishers to the cumulative impacts of management related business costs relative to revenues and, on the other side, community level views (i.e. government policy) regarding sustainable management of a public resource. Delivering effective fisheries management is therefore becoming dependent on gaining an adequate working understanding of all these influences so that managers themselves can be reliable and informed participants in the debate, also acting as mediators and interpreters where necessary.

What is also clearly emerging is the realisation that effective fisheries management requires a high level of discipline, for all participants, in maintaining a focus on medium to long term sector level performance of the fishery. This can often be in the face of debates where there are numerous threshold economic issues being faced at the individual or enterprise level.

This paper discusses each of the key factors contributing to the situation facing industry and places context around the impact they will have on the strategic and operational direction of the Australian Fisheries Management Authority (AFMA) and industry, as well as the political climate the Australian Government will face.

Introduction

Fish stocks are the natural capital of fisheries. However, if we examine the stock of natural capital in, for example, Commonwealth managed fisheries we get an unfortunate result. The Bureau of Rural Sciences Status Report on Commonwealth managed fisheries for 2004 states that 17 stocks are either overfished and/or that overfishing is occurring (Caton & McLoughlin in press). This is an increase from 16 in 2003 and 11 the year before that. In fact, the number of Commonwealth managed stocks classified as overfished has tripled in the last 10 years with most becoming overfished in the late 90's. However, the trend is still upwards and this is not unusual for many national fisheries jurisdictions. While nine of the stocks currently listed as overfished are the sole responsibility of the Australian Fisheries Management Authority (AFMA), the remainder of the 17 overfished stocks are jointly managed by AFMA and either Regional Fisheries Management Organisations (RFMO) or Joint Authorities. Yet, this negative trend has occurred during the same time as Australia has committed some $80-90 million per annum to fisheries research and assessment, implemented Ecologically Sustainable Development (ESD) based legislation in every jurisdiction and put management plans into place for all the major fisheries. Additionally, at Commonwealth level there are also formal links between environmental legislation and fisheries management to force a greater consideration of environmental impact of fisheries and the start of an ecosystem based approach to resource management.

Importantly, during the same period every stakeholder group has publicly espoused a commitment to sustainable and acceptable fishing practices and the wider public became convinced of the health benefits of eating seafood so presumably demand for seafood products has stayed strong. So what went wrong? What are the key factors that have led to these problems?

A reasonably informative analogy is that overfishing is like drawing on capital in a bank account rather than living on the interest, where the interest rate is equivalent to stock productivity. As capital declines the interest payments continue to get smaller, creating a rapid downward spiral - well managed fisheries generally aim to live off the interest. Furthermore, overfishing is generally accompanied by marked declines in catch per unit effort (CPUE). Declining CPUE leads to reduced economic efficiency of operations, meaning that fishers have to exert more fishing effort to meet expected gross revenue levels. This exacerbates the capital and interest spiral. This cycle of 'declining interest' from natural capital and reduced economic efficiency leads to considerable pressure being brought to bear on managers not to reduce catches of fishing effort. Unpredictable interannual environmental change also exacerbates the interest rate volatility. However, catch reductions are usually exactly what is required to rebuild natural capital and restore stock productivity back to maximum levels.

We contend that over the last 20 years, a focus on maintenance of the number and scale of enterprises in a fishery (i.e. avoidance of business failures) by using unsustainable catches to subsidise economically unsustainable businesses has led to an overall poor sector level performance for many fisheries. This has largely resulted from the lobbying efforts of the affected individuals and/or the view that business failures represent a failure of fisheries management itself. Apart from the fish stocks themselves, the big losers in this landscape are those well managed businesses who would normally survive at average sustainable catch levels but at are at risk in declining fisheries. Also, while the industry generally accepts those business failures caused by the actions of other businesses (such as hostile competition, buyouts or takeovers), it does not readily accept those business failures caused by fishery management actions designed to achieve a previously agreed policy or goal. It is no comfort that in Australian natural resource management, similar stories can be described for forestry and fresh water use.

Indeed, Walters and Martell (2004) state *"there is no general standard or procedure for constructing utility functions to combine or weigh the possible outcomes in public decision-making that involves multiple stakeholders with varying interests and aversions to particular outcomes. The simplest or 'expected value' utility measure would be to take an average of the outcomes, weighing each by it probability of occurrence. But this simple measure would not be acceptable to most fisheries stakeholders; people concerned with long-term conservation want to see differentially low utility placed on poor long-term outcomes, while people concerned with immediate income and employment want to see low utilities placed on outcomes that would involve short-term economic hardship.*

A common reaction from fishing stakeholders to uncertainty has been to demand that governments 'prove' that there will be a problem before introducing more restrictive harvest regulations. In decision theoretic terms, this amounts to demanding that the utility function for combining and weighing alternative outcomes place very low utility on outcomes that cause economic hardship and/or demanding that utilities for long-term outcomes be discounted at high rates."

If effective fisheries management is to be delivered, then a sector level focus with an understanding of the business environment facing fishing enterprises is necessary. This is the bioeconomic landscape in which the sector operates, with an overlay of social factors that will vary from port to port. Importantly, the objectives of fishery management will increasingly need to specify sector-level bioeconomic performance overall, as the key justification for a range of the actions necessary to recover from stressed, overfished or uneconomic fisheries. In terms of

Walters and Martell (2004) above, the fisheries management debate needs to shift towards low discount rates for long term outcomes.

Additional problems in Australian fisheries

There remains considerable latent effort in many Commonwealth and state managed fisheries both in terms of inactive access rights and less than full utilisation of those rights that are active. Generally, high levels of latent effort create considerable uncertainty for operators and leads to a race to fish on the basis that "if I don't someone else will".

Since 1992, AFMA has implemented Statutory Management Plans in five of it's current 23 defined fisheries. While three more plans are due to be implemented in 2005, there remains a lack of statutory management plans adding to operational uncertainty in what are already uncertain times for fishing businesses. It is also probable that legal challenges from entitlement holders on allocative issues in these fisheries may well delay implementation of these plans. Some other fisheries have limited entry and some spatial controls as the only management constraints. In similar terms to the point made above regarding latent effort, many Commonwealth fisheries remain overcapitalised with significant excess capacity. In some cases the management arrangements in place should lead to autonomous adjustment, however, a number of impediments (including total allowable catches (TACs) that, in effect, do not limit catch) have reduced the pace at which this adjustment has occurred.

By definition excess capacity is a sign of reduced economic efficiency. It leads to the dissipation of profits and added pressure on managers to keep TACs high to "keep my boat in work". Excess fishing capacity also reduces the asset value of standing fishing capacity. Indeed the losses on investments in fishing capacity can be very high in these situations. Managers of fisheries with considerable excess capacity will often hear fishers say, "I would be happy to get out but no-one wants to buy my boat" and may look to government to pay them to leave. For example, the Eastern Tuna and Billfish Fishery (ETBF) has less than 130 boats fishing but has more than 300 permits issued. Longline vessels in the ETBF averaged around 80 days fishing per year in 2004 and this is around a third of the world average for longline vessels elsewhere in the world. In the Gillnet, Hook and Trap (GHAT) sector of the Southern and Eastern Scalefish and Shark (SESS) Fishery only 110 vessels landed catch in the year to August 2004 but there are 270 permits issued.

Ageing fleets are also a symptom of poor economic conditions (i.e. lack of reinvestment) but they also lead to compromised competitiveness due to declines in efficiency relative to international fleets that supply the same markets including the Australian domestic market. Ageing fleets also signify a lack of confidence about return on further investment. In the SESS fishery approx 40% of the boats are 30 years or older. In the Northern Prawn Fishery (NPF) the average age of the fleet is also approximately 30 years.

However, there are still profits to be made in the seafood industry. Retail prices have remained stable or even grown against a backdrop of declining wholesale price. Australians have maintained their love affair with seafood following the 'fish is healthy' mantra of dieticians in the media. But fishers who solely supply wholesale markets must compete with many other suppliers. This often results in 'price taking' rather than 'price setting' with lower prices being paid to operators and retailers making more profit. In short, the same amount of money is being gained for the product that is sold to the consumer. However, the pie is being cut up in such a way that gives operators only a small portion.

Greater coordination of harvesting through measures exerted by industry associations has been seen elsewhere in the world in response to these situations. Fisherman's cooperatives also deal with this situation by setting price. However, the most effective solution for fishing businesses would appear to be vertical integration where the same company who catches the fish, processes

it and sells it to the consumer. Some sectors of the Australian fishing industry have responded in this way but on the whole there is a lack of vertical integration.

Fishing enterprises are inherently risky businesses and like other primary producers, production and profitability will be punctuated by good times and bad. Various Commonwealth fisheries have gone through high profit periods followed by periods of downturn but although the level of insulation has varied, industry has generally not positioned itself to survive a downturn. As for most other primary production sectors, the fishing industry needs to display dynamic efficiency in responding to long term changes and be resilient to any short term fluctuations. While fishery managers generally cannot control commodity prices, they do have the opportunity to reduce the risks of overfishing that compound industry's problems during market fluctuations.

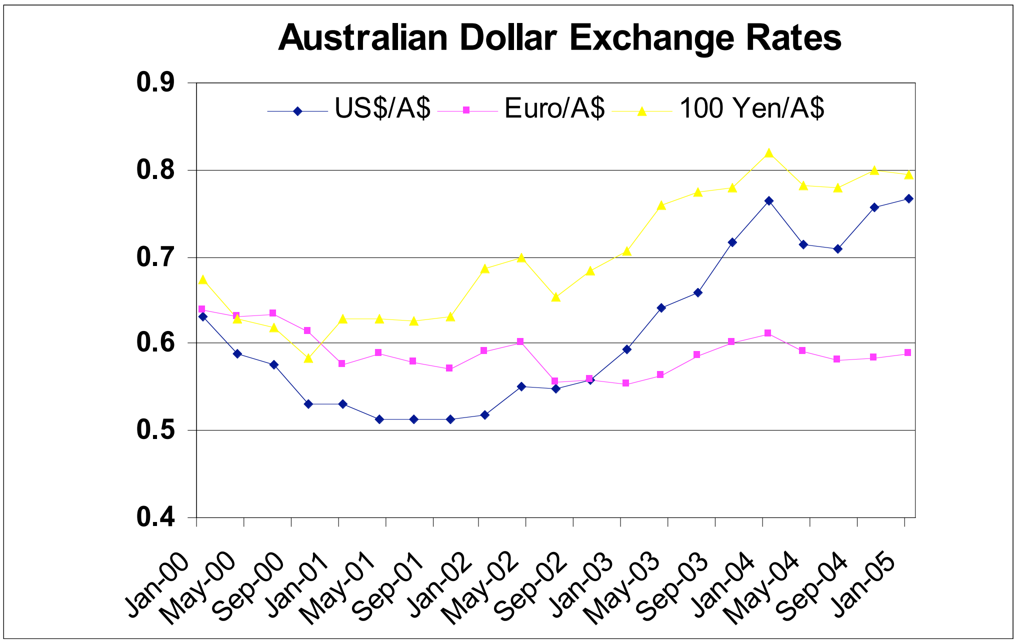
External economic drivers

(This section includes a collation of information from the Australian Bureau of Agricultural and Resource Economics.)

A relatively large proportion (over 30%) of the world's fisheries production enters world trade. For this reason, the prices of fisheries products are generally determined on world markets and the Australian dollar equivalent of these world market prices will be influenced by exchange rates. All things being equal, when the Australian dollar depreciates against major currencies, Australian dollar prices for seafood imports and exports rise. Equally when the Australian dollar appreciates against major currencies, Australian dollar prices for seafood imports and exports fall.

Figure 1 shows exchange rates for the Australian dollar against the main trading currencies for the seafood industry. Since mid 2003 the Australian dollar has appreciated sharply against the US dollar and the Japanese yen and modestly against the Euro. This has tended to reduce the prices received for exported seafood in Australian dollar terms, and the prices paid for imported seafood.

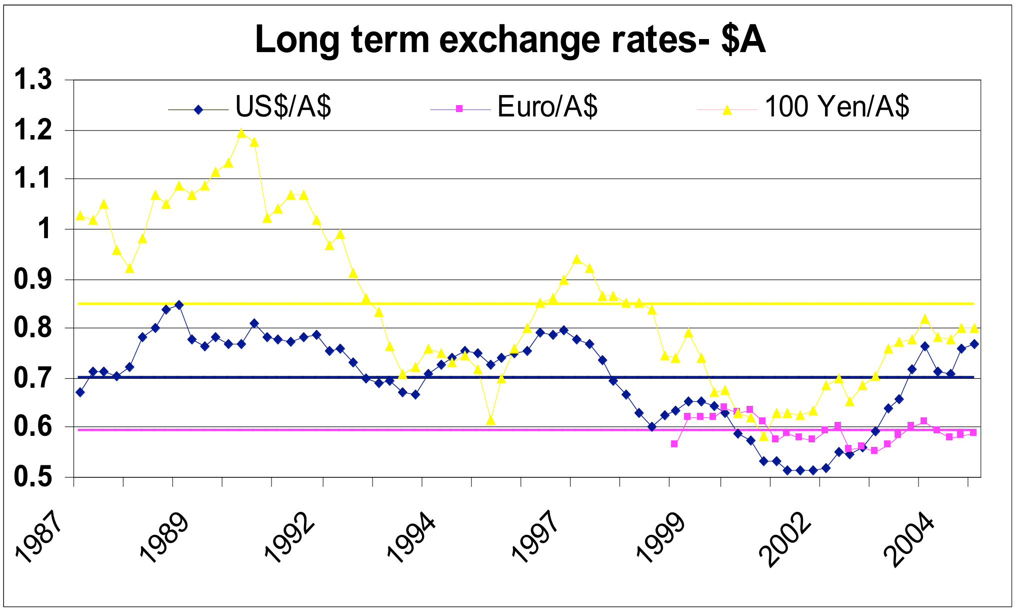
Figure 1



Source: Data provided by ABARE

However, the recent strengthening of the Australian dollar should be put into perspective over the longer time series as shown in Figure 2. As can be seen, recent Australian dollar exchange rates are not markedly different than the long term average (reference lines are plotted on Figure 2).

Figure 2



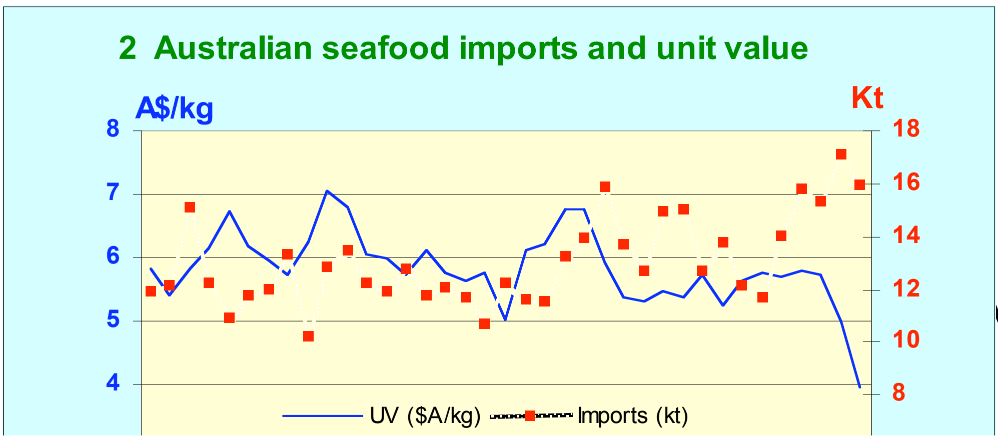
Source: Data provided by ABARE

Fuel price is discussed separately below, but it is worth noting here that the strong Australian dollar has mitigated to some extent, oil price increase. Had the Australian dollar remained at mid 90s levels against the US dollar, current fuel prices would be approximately 30% higher than current prices.

In 2003, seafood imports rose by 13 per cent in volume terms and by 4 per cent in value terms. Seafood imports in 2003 were 169 thousand tonnes valued at $923 million, compared with 149 thousand tonnes valued at $890 million in 2002. The average unit value of seafood imports was $5.48/kg, down 8 per cent on the average import unit value in 2003.

The volume of seafood imports has risen in recent months and the average unit value of imports has fallen. Since January 2001 until fairly recently, around 10-16 thousand tonnes of seafood was being imported each month at an average unit value in the range $5-7/kg (Figure 3). However, in December 2003, Australian seafood imports exceeded 17 thousand tonnes and the average import unit value of seafood imports fell to $3.94/kg. The trend is concerning.

Figure 3



March 1

Source: ABARE (UV= average unit value in $A/kg)

The three largest components of seafood imports are frozen fish fillets, canned fish, and fresh, chilled and frozen prawns. By value, each of these components made up just over 20 per cent of seafood imports in 2003. Because seafood imports are relatively unrestricted, and imported and domestically produced seafood is reasonably substitutable, the price at which seafood can be imported is likely to influence domestic seafood prices. In particular, because a large proportion of the fish caught in the south eastern fisheries are sold on the domestic market in competition with imports, the lower prices for imported fish is likely to affect fishing industry operator returns.

One of the major sources of frustration for the Australian industry is the lack of consistency between regulations applied to domestic and foreign production (eg environmental controls such as seabird threat abatement plans (TAP), turtle excluder devices (TED), Seal Excluder Devices (SED) and bycatch reduction devices (BRD)). Ongoing high levels of foreign fishing subsidies plus increases in global aquaculture production of key Australian fish commodities (eg prawns and tuna) have resulted in increased supply and competition in export markets.

Seafood export volume fell in 2003 by 7 per cent and the average export unit value of exports fell by 11 per cent, resulting in a 17 per cent fall in export value in 2003 (Table 1).

Table 1 Australian seafood exports

	Unit	**Whole tuna**	**Prawns**	**Rock lobster**	**Abalone**	**Other**	**All seafood**
2002							
Quantity	Kt	13.6	10.7	10.5	2.0	26.1	62.9
Value	$m	352.8	230.4	495.4	119.5	426.8	1 625.0
Unit value	$A/kg	26.03	21.44	47.12	59.18	16.38	25.84
Unit value **a**	US$/kg	14.21	11.71	25.73	32.31	8.94	14.11
2003							
Quantity	Kt	12.6	9.4	12.2	3.4	20.9	58.5
Value	$m	270.3	168.4	435.1	117.4	359.5	1 350.6
Unit value	$A/kg	21.47	17.94	35.75	34.75	17.17	23.10

Unit value **a**	US$/kg	14.11	11.79	23.50	22.84	11.29	15.19

a At an average US$/$A exchange rate of 0.546 in 2002 and 0.657 in 2003.

Source: ABARE analysis of ABS monthly trade data; exchange rate from Reserve Bank of Australia.

Export prices may influence domestic prices because seafood exporters are free to sell on either the export or the domestic market. Traditionally many high quality seafood products have been sold on the export market because higher returns can be obtained on this market. However, exporters may choose to switch product to the domestic market if a better price can be obtained. It is also worth noting that, despite its clean green image, valuable Australian seafood exports, particularly southern bluefin tuna and prawns, have come under fire from some foreign government agencies with regard to human health and environmental concerns.

Over the last three to four years the beach price (i.e. the price operators receive for their catch) for Australian caught seafood that is principally sold onto the Australian market has fallen.

Average annual prices for ten species of higher-value fish (that is, those that sell at higher prices per kilo- includes species not caught in Commonwealth waters) are shown in Table 2. At the Sydney Fish Market, prices for the higher value fish typically sold into the plate fish market held up reasonably well in 2003-2004, considering the increased quantities of product being imported and available on the domestic market from product that previously would have been exported.

Table 2 Average prices for selected higher-value fish: Sydney Fish Market A$/kg

	2001-02	2002-03	2003-04
Snapper			
Large	8.22	8.35	9.21
Medium	9.02	9.46	9.96
Small	10.32	10.28	10.74
Sand whiting			
Larger sizes	10.23	10.66	10.69
Small	8.94	9.16	8.98
Silver bream			
Larger sizes	8.73	9.04	10.02
Small	7.92	8.13	8.99
Yellowfin tuna	9.47	9.08	10.31
John Dory -All	9.28	9.53	8.90
Yellowtail kingfish-	6.81	7.56	7.43

All			
Blueye-All	9.93	9.10	9.23
Broadbill-All	10.27	11.47	10.50

Source: Sydney Fish Market as collated by ABARE.

The recent current higher prices for snapper and sand whiting reflected the reduced quantities of product available. For silver bream, price increases over the period reflect reduced catch available as a result of New South Wales estuary closures. For yellowfin tuna, prices have moved according to quantities sold.

The average price for John Dory held up reasonably well, considering the large quantities of product imported from New Zealand in recent times. Domestic prices for broadbill have also held up well, considering the volume of product being sold (through markets other than the Sydney Fish Market) that previously would have been exported.

Lower-value fish

Average annual prices for seven species of lower-value fish are shown in Table 3. What is most notable is that recent prices for the fish listed on this table have dropped relative to their value in 2001-02 or 2002-03. Important also to note that the list below contains many of the species caught in the Commonwealth SESS fishery.

Table 3 Average prices for selected lower-value fish: Sydney Fish Market A$/kg

	2001-02	2002-03	2003-04
Ling			
All	6.25	6.57	5.98
Tiger flathead			
Extra large	4.25	4.21	4.08
Large	3.96	3.92	3.71
Medium	2.81	2.83	2.67
Small	1.53	1.31	1.56
Ocean jackets-All	2.55	3.44	2.97
Redfish-All	1.65	1.71	1.59
Redspot whiting-All	2.21	2.57	2.48
Morwong-All	2.79	2.56	2.67
Mirror dory-All	2.58	2.52	2.55

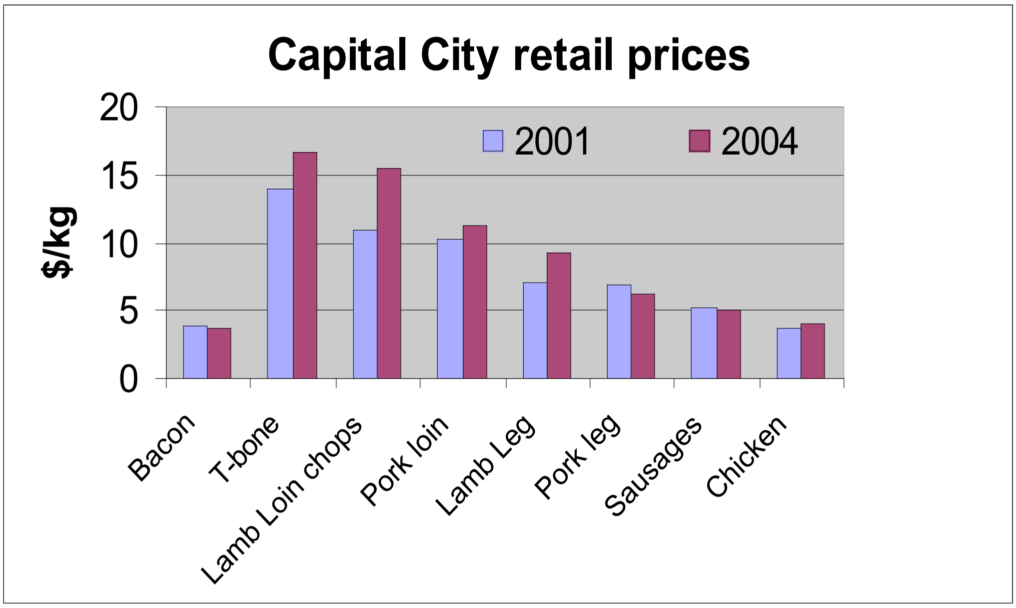
Source: Sydney Fish Market as collated by ABARE.

The volume of ling traded at the Sydney Fish Market has been declining since 1999-2000. The volume traded in 2004-05 is expected to be similar to levels in 2002-03, but prices are expected to continue to decline. Prices for most grades of tiger flathead have been flat or declining for the past three years. The price for ocean jackets tends to reflect the quantities traded, although the average price in 2003-04 was around 14 per cent lower than the average price in 2002-03. Prices for morwong have been flat or declining over the past three years despite the fact that the quantities traded have been lower than during the late 1990s. Prices for redfish, redspot whiting and mirror dory have also been flat or declining.

Domestic demand for fish will be affected by consumer reactions to, among other things, changes in the relative price of seafood and the price of substitutes such as meat. Quarterly retail prices for meat and fish are reported in the ABS publication *Average Retail Prices for Selected Items*. Between the September 2001 quarter and the September 2004 quarter, capital city prices for higher quality beef and lamb rose by 15-30 per cent at the retail level (Figure 4).

The rise in red meat prices has led to some product substitution such as white meats and seafood, the prices of which generally fell. It is possible that the strong rise in red meat prices in calendar 2004 increased domestic demand for fish and underpinned domestic fish prices. Part of the increased domestic demand for fish may also have been satisfied through an increase in imported fish products, hence the drop in prices for a number of domestic species competing in the market only as white flesh fish. However, most seafood remains an expensive meat option relative to other red and white meats.

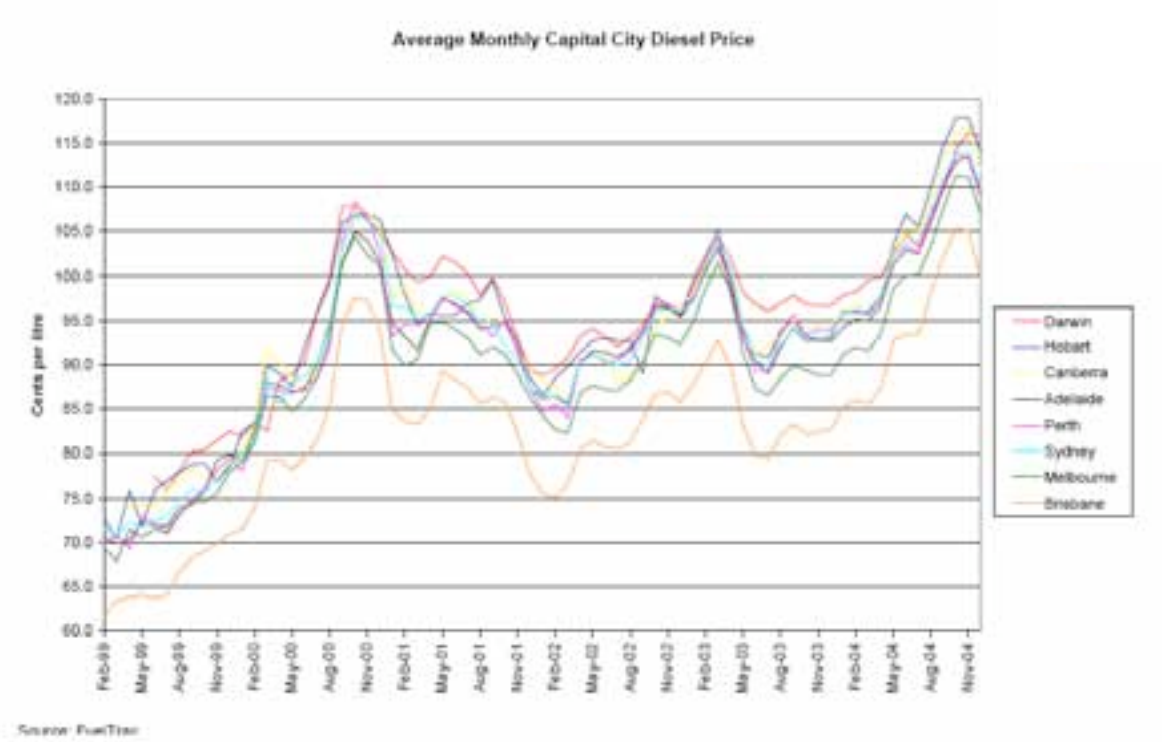
Figure 4



Increasing operating costs

Commercial fishing is a fuel intensive business. Diesel prices have jumped considerably over the last 6 years- somewhere in the order of 60% (Figure 5). Given that fuel costs account for up to 30% of harvesting costs in our fisheries, the effect on operators has been extreme. A concerning trend against this backdrop is the marked increase in average horsepower ratings of boats, particularly in the trawl fisheries. The cost to operators is further exacerbated by increases in travel distances to fishing grounds due to overfishing adjacent to major/convenient ports.

Figure 5



Insurance is another significant cost for the fishing industry. Given the global approach to the setting of base premiums, it is probable that the Australian industry is paying more than it should. If you look at the risk factors that insurance companies take into account (eg structure of access rights, survey standard, state of fish stocks, economic health) the Australian fishing industry still presents a lower risk than much of the remaining world fleet. There is no doubt that insurance companies place considerable weight on the economic and biological health of the individual fishery. For example, a Western Australia Rock lobster fisherman generally pays a premium of about 1% of the value insured while an East Coast Tuna operator may pay up to a 4% premium (Michael Gristwood, *pers.comm*)[1].

Figure 6 below show trends in AFMAs management costs relative to GVP. While these data do not include the full costs of management (eg many research and government costs outside AFMA are not included), it is clear that management costs have increased both in absolute terms and as a percentage of GVP over the last 4 years. As harvest levels move towards Maximum Sustainable Yield, there is generally a marked increase in the costs of assessments due to the need to resolve uncertainty in risks to the stock. At the same time profits decline due to the increased operating costs involved with taking each kilogram of fish beyond Maximum Economic Yield. Most Commonwealth fisheries operate at the 'high risk, high return, high cost' level of catch. Overlaying individual fisheries issues, there has been a marked increase in public pressure to enforce greater environmental responsibility, performance and transparency on fishing operations. Both these demands have resulted in higher costs of managing Australia's fisheries.

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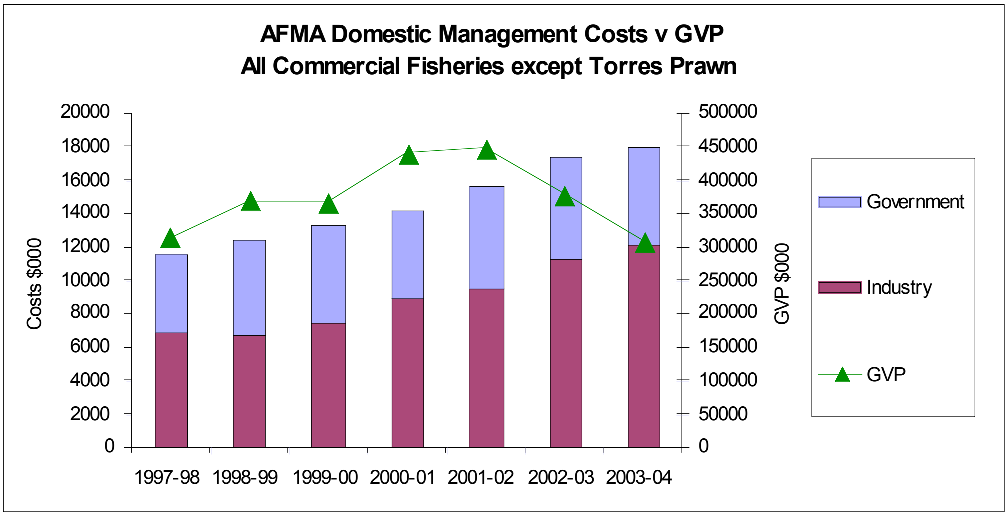
[1] Michael Gristwood, Manager- Sunderland Marine Mutual Insurance Company Limited

Figure 6



The past 10 years has also seen a dramatic increase in the amount of fisheries regulation dealing with aspects of fishing interactions outside target species. From research through to regulation there has been a marked increase in the direct and indirect costs to fisherman to deal with broader fisheries interaction issues. Examples include TAPs, SEDs, TEDs, BRDs, increased levels of observer coverage, area closures and operational changes.

Finally, declining profitability due to overfishing and other causes outlined above has had a marked impact on non-fishing factors mostly located in rural and regional Australia. Loss of profits from fishing has resulted in a loss of infrastructure and other supporting businesses - it has also resulted in the next generation looking outside the fishing business for career opportunity. Observed trends in demographics suggest that fewer younger people are choosing to move into fishing causing significant difficulties for current operators seeking young crew or even experienced skippers. The at-sea component of fishing operations is predominately male based leading to fishing being naturally difficult for modern families due to economic and social pressures. This means extended periods at sea are becoming even less attractive, especially when this is combined with low/declining profits and declining CPUE's mean even greater periods spent fishing to return the same amount of catch.

Conclusion

After reading the above, it is possible to gain the impression that fishery managers have done little to improve the circumstances facing the fishing industry or that they do not understand the business environment that the fishing industry faces. This would be unfair. Australian fishery managers have worked hard to develop key management approaches and respond to public concerns by increasing awareness of the industry's responsible approach to long term sustainability, in the context of difficult and changing economic circumstances. In many respects they lead the world in genuinely attempting to implement policies that are sometimes only theoretical frameworks (at best) in most other jurisdictions.

Some might suggest that during these tough times a more risk prone approach to harvest levels may be appropriate – indeed we are already seeing some in the fishing industry calling for this approach. As stated in the first paragraph of this paper, fish resources are the natural capital and further 'dipping' into this capital is not good business or natural resource management. The path ahead is clear- we must improve both the health of Australia's fish stocks and the economic efficiency of our fishing industry. What is not clear is how we follow that path. The effectiveness of our management may well then be simply a matter of the timeframes for dealing

with the problems that industry faces, in a partnership with the industry that has to do the adjusting.

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Cost-effective management of uncertainty in fisheries

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CSIRO Marine Research

Introduction

The management of fisheries under uncertainty is a topic that has attracted a huge literature in many disciplines over many years – in management and policy, in fisheries economics, in fisheries assessment and modelling, in statistics, and in operations research to name a few. Here I will not attempt to cover this topic in anything like a comprehensive manner. Nor in a technical manner. Rather I'll just provide some observations about the current situation and what I regard as lessons from what I have seen.

But first some context, with an emphasis on uncertainty. There is increasing concern, globally and in Australia, about the number of fisheries that are overfished and the broader ecological impacts of fishing. Fishing is happening in more places, taking a wider range of species, and with greater technological efficiency than ever. But some of the world's largest fisheries, and some of the most intensively researched and managed, are overfished, and some have spectacularly collapsed. In addition to the ecological damage, the socioeconomic costs of overfishing--even chronic overfishing rather than acute stock collapse--to regional human communities has been shown to be considerable (eg Anon. 2003). And to the extent that overfishing is unintentional, especially gross overfishing and stock collapse, this has fuelled concern that fisheries are being inadequately managed in the face of the uncertainties they face.

Furthermore the increased understanding of fisheries impacts on seabed habitats, by-catch species from seabirds to seahorses, food webs, and top predators has led to increased calls for management of the effects of fishing on the broader ecosystem. Motivations for this broadened mandate of fisheries management include a focus on production, through providing a more secure ecological basis for ongoing fishery production. But other 'goods, services and values' are increasingly being recognised and included in planning and management of responsible fisheries, as outlined in the FAO Code of Conduct for Responsible Fisheries (e.g. FAO 2003). Also, fisheries management is being increasingly considered along with other human uses of marine ecosystems – aquaculture, coastal development, shipping, oil and gas etc – in the sustainable use of marine ecosystems. And to this already formidable list can be added the prospect of global climate change. This is expected to change the productivity and functioning of ecosystems in new ways, and so remove a key assumption in almost all fisheries assessment and management – that of 'stationarity' which provides the basis for believing that information and understanding from that past is a useful guide to what might happen in the future.

And as the requirements for management of sustainable and responsible fishing are increasingly understood and broadened, more kinds of information and management intervention are potentially indicated. Increasingly, the kinds of issues that are being raised are more difficult to observe and to address through management intervention than those that arise from considering a target species in isolation. In a sense the uncertainties that affect fisheries management are increasing as understanding about more issues is required. And improved understanding sometimes reveals that there is greater uncertainty than we previously recognised.

So in this situation of increasing requirements and uncertainty, how can fisheries management provide, in a cost effective manner, an acceptable balance of socioeconomic outcomes and impacts on marine ecosystems?

Here I won't dwell on the critical social, political and instutional requirements for success. These include for example social understanding of and support for ecologically sustainable development; political support for policies and actions to achieve ecologically sustainable development (recognising that these often pit short term against long term outcomes and can have winners and losers among present constituents and stakeholders); and institutional capacity to reach and implement appropriate fishery management decisions. And I won't dwell on private sector investment strategies or financial drivers. All these aspects have a critical effect on the success of fishery management in dealing with uncertainty, and they deserve a full and different discussion in their own right. But here I'll just accept that they are in place and consider the management of uncertainty within fishery management decisions.

At the risk of over-simplifying, I think it comes down to four key points.

1. Clear recognition and selection of where in the catch-cost-risk spectrum the fishery should (or can afford) to be.
2. Clear standards for fishery targets, limits, and rebuilding, to answer the question 'what uncertainty?'.
3. Testing of management strategies against reasonable uncertainties to demonstrate that the desired outcomes are likely.
4. Developing a suite of assessment and management options that are reliable when low-cost management is appropriate or necessary.

1. Clear recognition and selection of where in the catch-management cost-risk spectrum the fishery should (or can afford) to be.

Figure 1 gives a schematic for the interaction between risk, management cost and catch in a fishery. The catch in this is how hard or aggressively the stock is harvested, and as this increases both the yield (a proportion of the maximum catch theoretically possible) and the between-year variability of the yield increases. The management cost combines the cost of management decision processes, information needs, implementing management measures and compliance. And it is broadly based on the current suite of commonly used management tools, such as input or output controls with the levels determined by an information based assessment. The management cost here is a proxy for the level of understanding, process and control that underpins the management decisions. Risk combines the chance and consequence of undesirable outcomes, including ecological and economic outcomes.

If highly aggressive catches are applied with low management cost then the risk is likely to be higher than the same catches with high cost management. For any level of management cost the risk is likely to increase as the level of catch increases. To meet a given level of risk usually implies use of some limited combination of catch and management cost.

Another way of looking at this is Figure 2. It illustrates that there are management cost-catch combinations that are likely to be unacceptable. And that there is a spectrum of combinations, extending from high catch - high cost to low catch - low cost, that are likely to give acceptable risk. For example:

At one extreme the management could:

- aim to achieve the maximum possible yield from the resource

- require frequent and detailed management plans and interventions
- require precise monitoring and frequent assessment and intervention
- need high management and R&D costs

At another extreme the management could:

- expect a lower yield than the maximum possible yield from the resource and include greater 'safety margins'
- use less frequent and more general management plans and interventions
- function acceptably with lower precision monitoring and infrequent assessment and intervention
- function acceptably with lower management and R&D costs

It is a management decision as to where to be in this spectrum of management cost and catch. And different approaches may be appropriate for different fisheries. Planning to extract the maximum possible yield from a resource may be entirely appropriate and justified by the returns from the resource. And it may be deliverable with appropriately honed management approaches. But the approach selected must be consistent as a package. An approach that aims to deliver the maximum possible catch from the resource without being able to afford or justify the processes and information needed to manage the risk of such high exploitation rates is unlikely to succeed for long. There are many solutions that are possible but whatever is selected must be practically achievable. And in this context it is noteworthy that a characteristic of fisheries that have demonstrated long-term sustainability is that they 'use lower exploitation rates that deliberately do not attempt to maximise biological productivity' (Hilborn et al 2003).

Schematics such as Figures 1 and 2 are not intended to be literally applied, but rather are intended to help with strategic considerations and choices. And the key message is that where to be in the spectrum of catch, management cost and risk is a management choice, but that it is not an unconstrained choice. Many fisheries find themselves at the high catch - high management cost situation without that having been a specific decision – rather it is often the cumulative outcome of a series of 'small' and seemingly unconnected decisions. Fisheries can find themselves running risks that are much higher than anticipated if they do not meet the costs required to effectively manage the risks of the approach adopted. Or conversely fisheries can find themselves having to deal with much higher costs than anticipated. Effective management of risk requires that this management choice be considered much more explicitly than it usually is.

2. Clear standards for fishery targets, limits, and rebuilding

The need for clear statements of targets, acceptable limits and rebuilding strategies is well established in fisheries management. These are required to be provided in fishery management plans by most jurisdictions, they are key to the nationally adopted ESD reporting Framework for Australian fisheries, and they are required by the Guidelines for the Ecologically Sustainable Management of Fisheries under the *Environment Protection and Biodiversity Conservation Act*. But there is a wide range of interpretation about what these targets and limits might be in different fisheries. To an extent it is expected and even desirable for different fisheries to have different operational targets, limits etc. – one size does not necessarily fit all when it comes to detailed operational applications and there must be scope to consider specific situations.

But without sufficient overall guidance on the standard required, this can be both inefficient and ineffective.

- Inefficient because of the costs of replicated decision-making and R&D as the same issues are repeatedly addressed. This is particularly likely in the consideration of risk and the management of uncertainty, because the very notion of the risks and uncertainties of concern flow directly from the standards that are to be met. Lack of clarity on the standard guarantees that consideration of the risks due to uncertainty, and the appropriate risk management measures, will be convoluted and long-winded. Furthermore, lack of a clearly articulated standard is an impediment to greater use of outsourcing of fishery assessment, management and audit functions and the benefits of competition in provision of these services. If the standard of the service cannot be specified it cannot be reliably outsourced. (This is discussed further in 4 below).

- Ineffective because more or less isolated development of targets and acceptable limits, and risk management strategies to achieve them, can fail to adequately address and balance the more general expectations that ultimately they may be judged against. These expectations come from a variety of sources nationally (e.g. in an Australian Commonwealth context the ESD and other requirements of the *Fisheries Management Act*, EPBC requirements and the BRS Status Reports) and internationally (e.g. the FAO development of minimum standards for responsible fisheries management). Furthermore, if the targets and acceptable limits cannot be clearly specified then the management strategies to achieve them also cannot be clearly specified, with the result that the selected strategies are less effective than they might otherwise be. (This is discussed further in 4 below.)

The standards required for targets, limits and rebuilding are fundamental to any consideration of risk, and lack of clarity about them results in unnecessary confusion, inconsistency, cost (e.g. unnecessary management process and inappropriate management measures), and the undermining of stakeholders' confidence. As a concrete example, the Northern Prawn Fishery has in the last couple of years gone through a major and costly process in which the appropriate targets and limits became the point of debate. Had there been greater clarity about the standard for fishery targets and limits, this process could have been a great deal shorter and easier, and if the end-point reached in this fishery was adopted more widely in the form of a standard, then there would be no need to repeat these same discussions when the same issues arise in other fisheries.

This is clearly a balance between setting clear generic standards, to ensure that all fisheries conform to broad expectations, without overly limiting the ability to find the most effective way to interpret and implement that standard in a particular fishery context. While getting this balance right poses challenges, the experience elsewhere suggests that this is both possible and desirable. For example New Zealand (e.g. Anon. 2003) provides guidelines and 'default' approaches to targets, limits and rebuilding requirements. Individual fisheries can take a different approach, but the default is the starting point. The US (NMFS 1998) goes further and has a set of national standards for fishery management, including targets, limits and rebuilding requirements (e.g. Table 2), that are specified in 'hard law' regulation. In both countries, in quite different ways, these standards provide the crucial setting for addressing and management of uncertainty in fisheries.

Cost effective management of uncertainty requires clarity about the standards being applied, especially in relation to the targets and acceptable limits of fishery depletions and impacts. There are good examples of how these might be specified, and we should both learn from and build on those experiences to develop standards that suit our requirements.

3. Testing of management strategies against reasonable uncertainties to demonstrate that the desired outcomes are likely.

Fisheries management systems, like many other management systems, use an adaptive management loop to help achieve desired outcomes despite uncertainty. This is used in a very wide variety of situations - for business financial performance management, for inventory management; for factory production management, and for automatic pilots. They all use a variation on the adaptive management cycle (Fig 3), which has as its basis (i) specification of measurable (operational) objectives, (ii) monitoring of indicators and calculation of performance measures in relation to the measurable objectives, (iii) management interventions triggered on the basis of the performance measures that are designed to correct departures from the intended objective, and (iv) periodic review of the management strategy described by steps i-iii. A distinction can be made between adaptive management and reactive management, based on the level of forward planning. Adaptive management involves design of the strategy, so that the monitoring and planned management response has been explicitly considered and selected as a package on the basis that it has a good chance of achieving the stated objectives. Designed adaptive management has proved capable of delivering the objectives despite considerable uncertainty in the system being managed. It does rely on some understanding about the kinds of uncertainty being encountered, and their likely effects. This is the distinction between the uncertainty we know about, and so to some extent can plan for, and the uncertainty we don't yet know about.

Fisheries management processes usually match the structure of the adaptive management loop well. There is usually a cycle of (often annual) stock assessments, which use monitoring information to derive performance measures, and subsequent review of management measures for the next period of management. But often the strategy is not considered and designed as a whole to give a good chance of success in the face of the kinds of uncertainty that might reasonably be expected. Often the selection of what is monitored (both 'routine monitoring' and targeted R&D), how monitoring data is analyzed and turned into performance measures (stock assessment), and how management interventions should be changed according to the status of the performance measures (the management response) are decided more or less separately - without explicit examination and testing of how well they work together as a management system. And because they are all parts of a system it is their combination, and not just the properties of any one element in isolation, that determines the overall effectiveness of the system in achieving management objectives. A highly targeted and effectively implemented management response is unlikely to deliver on overall objectives if it is informed by a very inaccurate stock assessment. And conversely an exact stock assessment would not contribute greatly to achieving management objectives if it is informing a poorly targeted and ineffectively implemented management response.

There are well developed methods to test the likely effectiveness of fisheries management strategies in the face of uncertainty, and they have been used in many countries and circumstances (see Sainsbury et al 2000). They have been applied qualitatively and quantitatively, and to the target species as well as to broader aspects of the marine ecosystem such as by-catch species and habitats. And a lot is known about the uncertainties and circumstances that have caused fishery management failure in the past, which provides a good basis for specifying at least 'the uncertainty we know about'. Where there is knowledge and understanding about the fishery in question some of these uncertainties can be reasonably dismissed. This testing will always be in a simpler setting than the real world, but the question should be asked – if a proposed management strategy fails in the simplified environment of the test then on what basis to we expect it to work in the much more complicated real world?

Proposed management strategies could and should be explicitly tested against a range of uncertainties that is reasonable for the fishery. This could be done cost-effectively through better identification of a common and default suite of key uncertainties for different kinds of fisheries and through close to automated testing procedures. That does not remove the need for sensible use of the results, or exclude use of a different suite of uncertainties and tests in specific circumstances. But it provides a structured way to include uncertainty in the management of fisheries based on prior experience of uncertainties that could cause management failure, and it can be applied in both information rich and information poor situations. In information poor situations the focus would be on strategies that were robust to a wide range of uncertainties that cannot be excluded. In information rich situations it is expected that the testing would be across a narrower range of uncertainties because some can be excluded. But in both cases the intention is the same. To develop, justify and use management strategies that have a good chance of delivering the management objectives despite the uncertainties that are reasonably to be expected in that fishery.

4. Developing a suite of assessment and management options that are reliable when low-cost management is appropriate or necessary.

There is a reasonable basis in existing knowledge and experience to address the first three points above. But point four is the area of relatively weak development, although there are serious efforts to find solutions going on in many places.

The obvious low cost management option is to reduce the catch. Even if there are improvements in low cost options it is likely that reducing the exploitation rate will continue to be a necessary part of risk management when there are few resources available to support management (i.e. the management decision processes, information needs, implementing management measures and compliance). But there are promising developments that could make many of the elements of a fisheries management strategy – monitoring, analysis of monitoring data (fishery assessment), management tools and compliance – more effective with limited resources. In Figure 1 these could have the effect of allowing a higher catch for the same cost and risk, or lowering the cost for the same catch and risk.

Some of these developments are:

- New technology to monitor catch and by-catch (eg video and image analysis), report location and activity (e.g. satellite based vessel monitoring systems), and to efficiently generate and manage logbook information (e.g. electronic logbooks and their communication).
- Use of industry, supported by training and quality assurance programs, to collect monitoring information on catches and implementation of management measures.
- Use of third party service providers, supported by training and quality assurance programs, for sustainability assessments.
- Greater use of spatial zoning to manage risk. This includes spatial zoning of gear types with different inherent impacts on the target species, by-catch or ecosystem, as well as zoning of the catch of target species to manage the age or size groups harvested. Such options are currently being developed and examined in the Commonwealth South East Fishery, using a consultative process and both qualitative and quantitative application of management strategy evaluation methods.
- Assessment methods that can transparently address risk and outcome standards despite limited information from the fishery, and allow better identification of where to target management effort. One development in this is the Ecological Risk Assessment project (Hobday et al 2004) being applied to Commonwealth fisheries. It contains a tiered system of qualitative and quantitative risk assessment methods,

with the more demanding quantitative methods only being triggered where the qualitative assessment indicates it is necessary and if cost-effective risk management measures are not available. Another is a project by the Marine Stewardship Council. It will use eight 'data poor' fisheries to test three different methods for third party assessment against its standard for sustainable fisheries. The three methods to be tested are based on (i) the Ecological Risk Assessment method mentioned above, (ii) Rapfish (eg Pitcher and Preikshot 2001) and related methods, and (iii) methods used in qualitative risk assessments for food safety.

- Recommended catch control rules that can reliably deliver risk and outcome standards despite limited information from the fishery. These can provide a tested and justifiable default method to set catch levels in situations with different levels of information and understanding. For example the guidelines developed for the Alaskan fisheries (Witherall et al 2000) give recommended catch control rules for situations that range from having nothing more than a catch history through to having a full quantitative risk and resource assessment. These methods result in lower average catches when there is less known about the resource stock and its condition.

There is need for a great deal more focus on developing fishery management approaches that are cost-effective and robust to uncertainty – including the high levels of uncertainty that result from very limited resourcing of the broad management function or having to meet outcome standards relating to ecosystem function. And the solutions can be expected to involve better use of technology, greater use of spatial management zones, the fishing industry as observer and implementer of management measures, third party assessments and audit, and an acceptable suite of both qualitative and quantitative fishery assessment methods and management strategies for different circumstances.

Discussion

The need for cost effective management of uncertainty is not unique to fisheries. In all endeavours we use what we know, try to manage the things we know we don't know, and get surprised by the things we don't realise we don't know. Management of uncertainty is a key aspect of almost all management systems – from managing small business to large scale production and engineering projects. And some of the basics are the same throughout. These include

- Have clear goals, and measurable or operational interpretations of them.
- Be able to measure performance with respect to those goals.
- Be prepared and able to adaptively respond to the results of performance measurement.
- Anticipate likely causes of difficulty or failure and have appropriate management responses planned.
- If there are some important uncertainties that cannot be cost-effectively detected and managed if they arise, or eliminated by cost-effective R&D, then ensure the overall management approach or strategy is robust and will work even if they do arise.

Fisheries management does face challenges from a high level of risk and uncertainty in achieving success. But many businesses and other endeavours successfully use these approaches to manage risk and uncertainty that is just as challenging to their success. The vagaries of supply, demand and exchange rates for example. If there is a specific problem in fisheries management it is that it has not sufficiently developed a culture of risk management that develops and uses these approaches, despite their success in many other contexts. But that does appear to be changing, both in Australia and elsewhere.

So a lot is possible, but nothing comes for free. In fisheries there are likely to be feasible strategies to achieve sustainability and sustainable development goals at the high yield – high cost and low yield – low cost ends of the spectrum. For high valued fisheries the high yield – high cost may be appropriate, but in any event it should be an active and supportable decision. The outcome standards and risks should be the same across that spectrum, but the tools, information needs and cost of management may be quite different. And so would the level and variability of the catch.

Many of the methods and approaches needed to effectively manage uncertainty in fisheries already exist, and there are some obvious areas for further development that are receiving attention. These approaches need to be used more coherently, consistently and frequently.

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Figures

Figure 1.

Schematic for the interaction between risk, management cost and catch in a fishery. The catch in this is how hard or aggressively the stock is harvested, and as this increases both the yield (a proportion of the maximum catch theoretically possible) and the between year variability of the yield increases. The management cost combines the cost of management decision processes, information needs, management measures and compliance. The management cost here is a proxy for the level of understanding, process and control that underpins the management decisions. Risk combines the chance and consequence of undesirable outcomes, including ecological and economic outcomes. The dashed line shows the consequences to the management cost and catch of a selected level of risk.

Figure 2.

Schematic of cost-catch combinations that are likely to be unacceptable, and the spectrum of combinations that are likely to give acceptable risk that extends from high catch- high cost to low catch-low cost.

Figure 3. The management cycle, with integrated evaluation and adaptive management (From Jones in press)

Tables

Table 1. Some example clarifications and standards provided in US regulation through the Magnuson-Stevens Fishery Conservation and Management Act. Additional operational interpretation is provided in guidelines which, for example (Witherall et al 2000), provide the interpretations of Maximum Systainable Yield (MSY), the fish stock biomass giving MSY (B_{MSY}) , the fishing mortality giving MSY (F_{MSY}) and proxies for them that are acceptable with different amounts and kinds of information available.

Optimum yield is a target and "is prescribed as such on the basis of the maximum sustainable yield from the fishery as *reduced* by any relevant economic, social, or ecological factor..."
Optimum yield is the yield obtained by fishing a stock at the MSY control rule (e.g. fishing mortality giving MSY) as *reduced* by any relevant economic, social, or ecological factor.
The fishing mortality giving MSY (F_{MSY}), or related MSY control rule, is a limit to be avoided rather than a target that can routinely be exceeded. Fishing at rates above this is overfishing.
Minimum Stock Size Threshold is the larger of (i) 0.5 B_{MSY} and (ii) the minimum biomass that would rebuild to B_{MSY} in 10 years if fished at F_{MSY}. Populations reduced below this minimum are overfished.
Rebuild stocks that are unacceptably far below B_{MSY} to B_{MSY}. The *minimum* timeframe for rebuilding is the time taken to rebuild in the absence of any fishing. - If this lower bound is less than 10 years then rebuilding time can be adjusted up to a *maximum* of 10 years for socioeconomic reasons. - If the lower bound is longer than 10 years then rebuilding time can be adjusted upwards for socioeconomic reasons to a *maximum* of the lower bound plus one mean generation time for the harvested species involved.