Evolution of New Zealand’s fisheries management frameworks to prevent overfishing

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Since 1986, New Zealand has managed its fisheries using a Quota Management System based on Individual Transferable Quotas. As is the case for many other fisheries organisations, New Zealand’s Fisheries Act requires a management target based on maximum sustainable yield (MSY), although the specific wording implies that this should be achieved by maintaining the stock biomass near or above the biomass level associated with MSY (i.e. B_{MSY}). The interpretation and implementation of this management target has evolved considerably over the last 25+ years. Initially, two alternative interpretations were developed: a constant catch approach and a constant fishing mortality approach, both of which included the concept of maintaining high catches with ‘an acceptable level of risk’. Subsequently, a Harvest Strategy Standard that includes biomass limits, biomass or fishing mortality targets, risk tolerance criteria and specifications for rebuilding plans has been formulated and endorsed. The Harvest Strategy Standard is supported by operational guidelines in which methods for defining and estimating fishing mortality in multi-fleet, multi-fisheries situations have been developed, and approaches for defining realistic (‘real world’) rather than deterministic estimates of B_{MSY} are currently underway. Throughout, New Zealand has put considerable effort into rebuilding overfished stocks and attempting to define and use appropriate proxies for MSY-based reference points for low knowledge stocks.

Keywords: overfishing, New Zealand, fisheries management, maximum sustainable yield

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Introduction

New Zealand was amongst the first of countries to adopt individual transferable quotas (ITQs) as a primary means of managing its fisheries. Although several other countries adopted ITQs for specific fisheries at about the same time, with many more added progressively ever since, New Zealand has applied ITQs more comprehensively than any other country. Of course, ITQs are just one part of the overall fisheries management system, albeit an important part. The system as a whole is called the Quota Management System (QMS). There have been numerous papers and books written that have traced the evolution of the system from its inception through to various points in time, and/or examined specific issues (e.g. Annala et al. 1991, Sissenwine and Mace 1992, Annala 1996, Bess 2000, 2001, 2005; Connor 2001, Hersoug 2002, Yandle 2008).

However, no papers to date have specifically focussed on the role of the system in preventing overfishing. In fact, New Zealand is one of the few countries that has primarily adopted biomass targets rather than fishing mortality targets or limits. This paper traces the evolution of those aspects of the fisheries management framework that specifically relate to avoiding overfishing and the reduction of stock size to unacceptable levels.

Initial design of the QMS

New Zealand implemented a comprehensive ITQ system on 1 October 1986, following the successful adoption of related ‘enterprise allocations’ in newly established deepwater fisheries in 1982. Individual quotas were based on catch histories with fixed amounts of quota (defined by weight) issued in perpetuity (Sissenwine and Mace 1992). The New Zealand Government intended to explicitly enter the market to buy or sell quota should there be a need for a decrease or an increase in the Total Allowable Catch (TAC). At the time it was believed that there was scope for further increases in TACs in deepwater fisheries, and that the same might also apply to inshore fisheries once those that had become depleted were rebuilt. However, for various reasons, including over-optimism about the potential for quota increases to be sold to provide revenue to the government, and a related need to buy back quota to reduce the TACs for orange roughy, the ITQ system was changed from fixed to proportional on 1 April 1990.

Early alternative interpretations of MSY

New Zealand’s fisheries management system has generally been focussed on moving stocks towards, or maintaining stocks at, the biomass associated with the maximum sustainable yield (i.e. B_{MSY}).

The New Zealand Fisheries Act 1996 defines the maximum sustainable yield (MSY) as “the greatest yield that can be achieved over time while maintaining the stock’s productive capacity, having regard to the population dynamics of the stock and any environmental factors that influence the stock”.

Under section 13 of the Act, the Minister of Fisheries is required to set a TAC for each QMS stock that maintains the stock “at or above a level that can produce the maximum sustainable yield, having regard to the interdependence of stocks.” Where the level of a stock is below that which can produce MSY, the Minister must set a TAC that:
enables the level of any stock whose current level is below that which can produce the maximum sustainable yield to be altered—

(i) in a way and at a rate that will result in the stock being restored to or above a level that can produce the maximum sustainable yield, having regard to the interdependence of stocks; and

(ii) within a period appropriate to the stock, having regard to the biological characteristics of the stock and any environmental conditions affecting the stock.

**MCY, MAY and CAY**

The initial design of the ITQ system as one based on absolute tonnages valid in perpetuity, rather than percentages of a variable TAC, led scientists at the time to examine the pros and cons of alternative harvest strategies, particularly constant catch versus constant fishing mortality strategies (Mace 1988). Even at that time, there was a long history of studies showing that application of the (deterministic or stochastic average) MSY as a constant catch in a variable (stochastic) environment is not sustainable (Doubleday 1976, Beddington and May 1977, Horwood et al. 1979, Kirkwood 1981). This is illustrated in Figure 1, which shows the stock size for a model-generated stock with no fishing (green line), the stock size for the same stock fished perfectly at F_{MSY} (blue line, upper graph), the yield when that stock is fished perfectly at F_{MSY} (blue line, lower graph), and the consequences of attempting to take the MSY (calculated as the average yield over a 1000 year simulation from the F_{MSY} harvest strategy; red lines). This shows that while stock size is fluctuating high, attempting to take MSY as a constant yield (red line, lower graph) results in relatively high stock sizes (red line, upper graph), but when stock size declines, continued attempts to extract the same constant yield result in stock collapse.

Recognising the necessity of taking environmental variation and the consequent dynamic nature of fish populations into account in order to interpret MSY as a static harvest, the term MSY should be taken to mean the maximum level of constant yield (MCY) that satisfies the constraint that stock size will not fall below some minimum acceptable level even if production is poor during a series of years (Sissenwine 1978). This will by necessity be lower – often much lower – than the yields that can be obtained by varying annual catches in response to fluctuations in stock size. In the latter case, MSY is often equated with the maximum long-term average yield (MAY; Ricker 1975, Doubleday 1976, Sissenwine 1978). In New Zealand, the annual realisation of MAY is referred to as the Current Annual Yield (CAY), which is generally obtained by applying a constant F_{MSY} strategy to the current or projected exploitable biomass.

Therefore, if it is desirable to maintain TACs at constant levels over long periods of time (e.g. because ITQs are denoted as absolute tonnages, because the fishing industry requires stability in catches, or because there is insufficient research or monitoring to change TACs very often), it is essential to recognise the trade-off in long-term average catches (e.g. MCY versus MAY), and in the risk to stock sustainability (Figure 2).
Figure 1. The effect of attempting to extract the maximum average yield (MAY) as a constant annual catch.

Figure 2. Hypothetical relationship between the Maximum Constant Yield (MCY), Maximum Average Yield (MAY) and Current Annual Yield (CAY). Based on Mace (1988) and Mace and Sissenwine (1989).

The terms MCY, MAY and CAY were first introduced into New Zealand’s fisheries management framework in 1988 in the form of “Guide to Biological Reference Points for Fisheries Assessment.”
Meetings”, which was, and still is, published along with the annual summary of stock assessment results. Further guidance was provided in 1992 by suggesting that the “acceptable level of risk” be interpreted as the probability that biomass falls below 20% of the unharvested level ($B_0$) is less than 10% for all types of harvest strategies (Francis 1992).

While the influence of harvest strategies on calculations of MSY and long-term yields might seem like a fundamental and long-accepted result from the theory and practice of fish population dynamics, it was not widely appreciated at the time it was introduced into New Zealand’s fisheries management framework, and still tends to be poorly understood by many today. For example, the results obtained by Francis (1992) and others showed that MCY strategies tended to result in lower yields than CAY strategies, but also in higher average stock sizes. This led to the common misconception that MCY strategies are inherently conservative and, as such, estimates based on recommended methods for calculating MCY were often not taken seriously, or were considered to be lower bounds on an appropriate TAC. This of course does not take into account the risk to stock sustainability that constant catch strategies impose.

Other developments

While the “Guide to Biological Reference Points for Fisheries Assessment Meetings” has remained relatively static since about 1992, stock assessment methods have continued to evolve to explore alternative methods for providing advice on TAC levels. For example, one approach that has frequently been use in the recent past and tends to be used commonly for full age-structured assessments nowadays is to conduct stock projections based on alternative TAC levels for 5 or so years into the future, and to base short-term TACs on one or more performance measures that are output from these projections. Another approach that is considered to have high credibility but has not so far been used for many stocks is a Management Strategy Evaluation (MSE), which evaluates alternative harvest strategies against a range of performance measures. Rock lobster is the main species for which MSEs have so far been applied (e.g. Haist et al. 2011).

The formulation of a specific harvest strategy standard has been particularly instrumental in accelerating the evolution and adoption of biological reference points and performance measures for preventing overfishing.

The Harvest Strategy Standard

A formal harvest strategy standard was developed for the first time over the period 2005-08. Prior to this, New Zealand had primarily focussed on moving stocks towards $B_{MSY}$ from above or below as its key fisheries management objective (see above), although the risk constraint of less than a 10% probability of biomass falling below 20% $B_0$ was also often applied. The role of $B_{MSY}$ and risk constraints was formalised and expanded in the Harvest Strategy Standard for New Zealand Fisheries (New Zealand Ministry of Fisheries 2008). In addition, the need to consider fishing mortality or exploitation rates as explicit biological reference points was introduced. Fishing mortality targets had already been used in a few fisheries, notably scallop fisheries, prior to this period, but fishing mortality trajectories were generally not presented as output from stock assessment models, let alone being considered as reference points.
The Harvest Strategy Standard for New Zealand Fisheries is a policy statement of best practice in relation to the setting of fishery and stock targets and limits for fish stocks in the quota management system. It requires, at the minimum, the specification of a target based on either a biomass or fishing mortality rate, a soft limit set at ½ B_{MSY} or 20% B_0, whichever is higher, and a hard limit set at ¼ B_{MSY} or 10% B_0, whichever is higher. For stocks that have fallen below the soft limit, a formal, time-constrained rebuilding plan is required to rebuild the stock back to the target level in a timeframe between T_{min} and twice T_{min}, with at least a 70% probability, where T_{min} is defined as the theoretical number of years required to rebuild a stock to the target in the absence of fishing. For stocks that have fallen below the hard limit, closure of target fisheries is to be considered.

The relationship between the target, soft limit, hard limit and an optional threshold is illustrated in Figure 3.

![Figure 3](image)

**Figure 3.** Relationship between the target, soft limit and hard limit specified in the Harvest Strategy Standard (New Zealand Ministry of Fisheries 2008).

The Harvest Strategy Standard is supported by a set of Operational Guidelines (New Zealand Ministry of Fisheries 2011a) that is a living document intended to be updated periodically as new analyses are completed. It consists of two parts: technical guidelines and implementation guidelines. The technical guidelines provide, among other things, default target and limit reference points, methods of calculating fishing mortality (fishing intensity) in multi-stock, multi-fleet fisheries, example control rules (Figure 4), background information on the rationale behind the metrics chosen in the Harvest Strategy Standard, and the international and historical context for harvest strategies.
The Harvest Strategy Standard characterises fishery or stock status in the following way:

- If the MSY-compatible fishing mortality rate, $F_{\text{MSY}}$, or an appropriate proxy is exceeded on average, overfishing will be deemed to have been occurring, because stocks fished at rates exceeding $F_{\text{MSY}}$ will ultimately be depleted below $B_{\text{MSY}}$.

- A stock that is determined to be below the soft limit will be designated as depleted [or overfished] and in need of rebuilding.

- A stock that is determined to be below the hard limit will be designated as collapsed.

For stocks with a full stock assessment, New Zealand sometimes presents the trajectories of biomass and fishing mortality in the form of a phase plot, often referred to as a “snail trail” that depicts the undesirable overfished/overfishing parameter spaces (Figure 5).

Default recommended proxies for the common forms of proxies for biomass and fishing mortality targets are illustrated in Table 1.

### Outcomes for stock status

Since the Harvest Strategy Standard was adopted in 2008, progressively more stocks have been assessed against it. Unlike most other countries, New Zealand also presents summaries of stock status relative to management targets, although stock status assessments relative to the biomass limits and overfishing threshold continue to gain prominence.
**Figure 5.** Example ‘snail trail’ for a hypothetical trajectory showing the relationship of fishing mortality and biomass to the characterisations of ‘overfishing’ and ‘overfished’.

**Table 1.** Recommended default proxies for $B_{MSY}$ (expressed as %$B_0$) and $F_{MSY}$ (expressed as $F_{PR}$ levels from spawning biomass per recruit analysis). From the Operational Guidelines for the Harvest Strategy Standard (New Zealand Ministry of Fisheries 2011a).

<table>
<thead>
<tr>
<th>Productivity level</th>
<th>%$B_0$</th>
<th>$F_{PR}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>High productivity</td>
<td>25%</td>
<td>$F_{30%}$</td>
</tr>
<tr>
<td>Medium productivity</td>
<td>35%</td>
<td>$F_{40%}$</td>
</tr>
<tr>
<td>Low productivity</td>
<td>40%</td>
<td>$F_{45%}$</td>
</tr>
<tr>
<td>Very low productivity</td>
<td>$\geq 45%$</td>
<td>$\leq F_{50%}$</td>
</tr>
</tbody>
</table>

1. The most commonly recommended and used single species %$B_0$ target reference point is 40% $B_0$.
2. The most commonly recommended and used single species $F_{PR}$ target reference point is $F_{40\%}$.
3. A target of 60% $B_0$ is currently used for Cascade Plateau orange roughy in Australia; this is the only Australian orange roughy fishery that is currently open for target fishing.
4. Maximum sustainable yield for U.S. west coast rockfish has been estimated to be as low as $F_{70\%}$ for the least resilience of these species (Dorn 2002). The default proxy for west coast rockfish as a whole is $F_{50\%}$.
There are a total of 636 fish stocks in New Zealand’s quota management system, although 286 of these are ‘nominal’ or ‘administrative’ stocks. Of the remaining 350 stocks, in 2011 there was sufficient information to assess 123 relative to the management target, 127 relative to the soft limit, 164 relative to the hard limit and 103 relative to the overfishing threshold (Figure 6; New Zealand Ministry of Fisheries 2011b). The reason that it is possible to assess more stocks relative to the biomass limits, compared to the management target is that there is sometimes sufficient information to determine that a stock is likely to be above, say, the hard limit, even though there may be insufficient information to state whether it is above or below the management target. The lower number of stocks for which the status relative to overfishing can be determined reflects the legacy of a management system based on biomass reference points rather than fishing mortality reference points.

Figure 6. The status of New Zealand’s fish stocks relative to the fisheries management target, the soft limit, the hard limit and the overfishing threshold over the period 2009-11 (or 2008-11 in the case of the management target).
Although New Zealand has a relatively much higher proportion of stocks of unknown status than does the United States, the proportion of stocks of known status that were overfished in 2011 was roughly similar. In New Zealand, 15.0% of stocks of known status were classified as overfished, compared to 23.2% in the US. New Zealand was overfishing 21.4% stocks of known status compared to 15.8% for the US.

**Figure 7.** A comparison of the status of stocks in New Zealand and the United States in terms of the number of stocks of known and unknown status and the relative proportions of stocks of known status that were of unfavourable status (red) compared to favourable status (green) in 2011.

### Rethinking \( B_{\text{MSY}} \)

The concept of MSY (and the related quantities \( B_{\text{MSY}} \) and \( F_{\text{MSY}} \)) has received considerable criticism over the past 30-40 years. In New Zealand and other countries or fisheries management organisations that express management targets or limits in terms of \( \%B_0 \), the criticism mainly relates to targets that the public perceives to be relatively low percentages of the unfished level (e.g. until recently, the target for snapper fisheries was of the order of 20% \( B_0 \); it has since been revised upwards to the default of 40% \( B_0 \)). The issue is exacerbated in countries like New Zealand where a number of new fisheries have been initiated in the last 20-30 years, resulting in an explicit fishing down phase. The lay public generally does not understand why fish populations need to be reduced in size in order to extract a sustainable yield.

In addition, a number of fisheries scientists insist that the only valid way of calculating MSY is from deterministic models, or as the averages from stochastic models. These tend to give estimates of \( B_{\text{MSY}} \) of the order of 17-26% \( B_0 \). Whether the estimates are derived from deterministic models or as averages from stochastic models, such interpretations tend to make a number of simplifying assumptions. First and foremost they assume that the harvest strategy that is adopted in the real
world is the same as the one incorporated into, or implied by, the estimation model. They also assume perfect knowledge about catches and biological parameters, perfect knowledge of the stock-recruitment relationship (particularly knowledge of the steepness parameter), the potential for autocorrelation in recruitment, perfect stock assessments, and perfect management implementation, among other things. In general they also fail to explicitly incorporate acceptable levels of risk tolerance. Explicit recognition of any or all of these factors almost invariably results in higher estimates of B_{MSY} (and lower estimates of MSY) (Francis 1992, Francis and Mace 2005).

These considerations have led to the increasing adoption of 40% B₀ as the default management target for New Zealand fish stocks. However, it is not possible to estimate B₀ for the majority of stocks under management. A number of approaches have therefore been developed to provide proxies for B_{MSY} and %B₀ targets for low information stocks. These include ‘conceptual B_{MSY}’ reference points, which are used in cases where the relationship between CPUE and abundance can be assumed to be more or less proportional, or where some other form of relationship has been derived from data. In these cases, it may be reasonable to select an appropriate historical period when both CPUE and catches were relatively high and to use this CPUE level as a target (New Zealand Ministry of Fisheries 2011a). Utilisation of reference periods from CPUE trajectories in other circumstances is also currently being investigated.

**Conclusions**

Since 1986, New Zealand’s fisheries management framework has evolved from one that denominated quota shares in terms of absolute tonnages valid in perpetuity, to one that reconfigured quota shares as a specified proportion of a potentially variable TAC with the main goal of management being the continual adjustment of TACs to move stocks towards B_{MSY} from above or below, to one that has also incorporated biomass limits and overfishing thresholds. More recently, MSY-related targets are being considered in an ecosystem context with consideration given to the precautionary approach. There has also been a move towards consideration of the benefits of managing above B_{MSY} in terms of potential additional economic benefits along with concomitant reductions in the risk to the stock (e.g. by adopting reference points related to maximum economic yield). Further work is required on approaches to use for stocks where there is insufficient information to estimate the specified biological (or economic) reference points, or to determine the status of stocks relative to these points.
References


