Harvest Strategy Standard

Standards for Stocks

Managed Under s 13 of the Fisheries Act

Discussion Document

Ministry of Fisheries
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Contents

PART ONE: INTRODUCTORY COMMENTS

Introduction

1 The Ministry of Fisheries is developing standards to govern the harvesting of fish. The goal is to ensure our fish resources are well-managed with a good balance between sustainability and utilisation. The standards will ensure that everyone is clear about how fisheries are managed and how performance is measured.

2 This standard is among the first to be developed. It will have a significant impact on the way fisheries are managed and is complex. The development of the harvest strategy standard has been informed by two workshops with stakeholders and international experts in December 2004 and February 2005. Following on from those workshops the Ministry has developed the approach documented here. The categories of standards that are proposed, the key inputs to each category of harvest strategy standard, and the content of the harvest strategy standard are explained in this paper. The paper contains three parts: introductory comments, a brief overview of the approach, and a more detailed explanation of the approach.

Scope

3 In undertaking the task of developing standards, the initial focus will be to set standards that apply to QMS stocks. There are 94 species (& species groupings) currently managed under the QMS. The majority of marine species remain outside the QMS, but most of these contribute little, if any, to the catches of any fishing sectors and to commercial exports. Over time, the Ministry will develop standards that govern the harvest of all species and the impacts of fishing on aquatic life and habitats.

4 For QMS stocks, legislation sets out three basic management options:

- managing to a defined population size at or above the level that can produce the maximum sustainable yield (or catch) (s 13 of the Fisheries Act 1996);
- managing to an alternative population size other than one that can produce the maximum sustainable yield(s) for species that are enhanced, rotationally fished, form part of a larger highly migratory species, or where it is not possible to estimate MSY (s 14 of the of the Fisheries Act 1996); and
- managing to a population size that will produce less than the maximum sustainable yield for bycatch stocks in order to maintain the desired harvest level of target stocks (s 14B of the of the Fisheries Act 1996).

5 The Act places constraints around the use of each of the three management options. This paper addresses the first of the options available for managing QMS stocks. It has been selected because the majority of QMS stocks are managed on this basis. Standards have been developed to ensure that stocks are managed in a manner consistent with the legislative options and that management across different stocks is consistent. Not all fisheries, including those in the QMS, are necessarily suited to management under s 13. However, if it does apply then there is a need to define through standards the minimal requirements necessary to comply with s 13. Thereafter, there is a need to implement the standards and evaluate fisheries against those standards.

Role of Standards

6 Standards are a critical element in enabling Government to deliver on desired fisheries outcomes, including the legal obligations stated in the Fisheries Act 1996. Outcomes represent the results desired across fisheries. Standards form the required level of performance necessary to achieve those outcomes. As such they are a statement by Government of what it considers to be the minimum level necessary to ensure sustainable fisheries.

7 The harvest strategy standard is a key means of ensuring the balance between sustainability and utilisation of our fisheries resources. By ensuring that stocks are adequately maintained, both current and future generations of New Zealanders can obtain the full commercial, recreational and cultural benefits from their use.

8 The harvest strategy standard will provide guidance to fisheries managers when advising the Minister on setting and adjusting TACs and will be a key determinant of the nature of management action. This will provide clarity and transparency to stakeholders and allow them to plan their activities with increased certainty about what the expected targets are and what management interventions are likely if those targets are not met.

9 Standards are not intended to be a substitute for the legal obligations in the Fisheries Act 1996. They do not fetter the discretion of the Ministry or the Minister. There is a legal requirement that each case is decided on its own merits, without rigid adherence to a set of policy guidelines or standards. Where appropriate, decision makers must be willing to consider alternative approaches to those outlined in the harvest strategy standard. However, standards do constitute the generic approach that is applicable in the majority of situations. As a general rule there must be sound reasons for acting outside the terms of these standards.

Objectives of the Harvest Strategy Standard

10 For QMS stocks there is an explicit legal requirement to set a catch limit (a total allowable catch or TAC). It is the requirements in the fisheries legislation as to how the TAC is to be set that provide the basis for using a standards approach.

11 For the majority of QMS stocks, there is a legal requirement to set a TAC that maintains a fishstock at or above a level that can produce the maximum sustainable yield (MSY). When the population size falls below this level (i.e. when it cannot produce the expected maximum sustainable yield), then the TAC must be reduced to enable the population to be rebuilt. When rebuilding, or fishing down, the population to the target biomass level, there is a requirement to take into account relevant social, cultural and economic factors.

12 The Fisheries Act 1996 specifies the desired performance level. The objective is to manage at or above a population size or biomass that can produce MSY. The biomass corresponding to MSY, B_{MSY}, represents the *average* population size that will result from fishing a population using an MSY harvest strategy. However, it is not possible to continually maintain a stock at this average level because all stocks fluctuate naturally even in the absence of fishing. Therefore, achieving B_{MSY} on average generally means allowing a stock to fluctuate about this level, but ensuring that it does not drop "too low" or become overfished. To the extent possible, the situation where a stock is overfished is

to be avoided as it reduces the long term yield available to fishers and increases the risk to the long term sustainability of the stock.

13 One way of ensuring that fluctuations are within an acceptable range is to maintain fishing mortality rates near or below F_{MSY}, the fishing mortality rate that produces MSY on average (also called the maximum average yield). F_{MSY} is a reference point that is an internationally recognised target or limit in many fisheries.[1]

14 The key tasks are to estimate F_{MSY} and B_{MSY}. Numeric values of F_{MSY} and B_{MSY} differ for every fish stock. The rate at which biomass declines or increases, with and without fishing, also varies widely.

15 To calculate reliable estimates of F_{MSY} and B_{MSY}, information about a range of variables is required on an on-going basis. In practice, there is neither the resources nor the information available, nor is it necessarily cost-effective, to estimate F_{MSY} and B_{MSY} for every management unit in the QMS. In such cases appropriate proxies for F_{MSY} and B_{MSY} will be adopted.

16 The objective in all instances, making use of the available information and taking account of the individual characteristics of each species, is to ensure that stocks are managed in a manner consistent with the Minister's statutory obligation to set a TAC at a level that maintains a fishstock at or above B_{MSY} on average. The role of the harvest strategy standard is to provide some clarity and consistency as to how this objective can be achieved.

17 The harvest strategy standard is a statement by Government of what it considers to be the minimum necessary to ensure sustainable fisheries. Tangata whenua and stakeholders may decide that they wish to incur less sustainability risk (e.g. by maintaining stocks at higher biomass) than that proposed in the harvest strategy standard. The mechanism for achieving this is through the implementation of fisheries plans.

Implementation of Harvest Strategy Standard

18 It is anticipated that the harvest strategy standard, once approved, will be implemented in fisheries plans. A fisheries plan is an agreement between parties to manage the fishery in a particular way. Fisheries plans will explicitly say what tangata whenua, stakeholders, and the Ministry want from a fishery, how to get there, and how to ensure that plan objectives are met. The goal of fisheries plans is to improve fisheries management by creating greater certainty, better management, more effective controls, less conflict, and better ability to plan fishing activities to achieve specific goals.

19 Standards will provide a basis upon which to first develop and then in subsequent years evaluate the performance of a fisheries plan. Standards will provide more transparency and certainty to fisheries managers and the public about the minimum level of performance required by Government to be achieved in fisheries plans. The Ministry will monitor fisheries to ensure the standards are implemented, or where an alternative approach is adopted, that it will provide an equivalent minimum level of performance in the sense that alternative approaches must deliver a sustainability risk that is no greater than that which would be achieved by the harvest strategies detailed in this standard.

[1] The relationship between exploitation rates and fishing mortality rates is outlined in Appendix III.

Where a fishery fails to meet a harvest strategy standard (or the effective alternative), the fisheries managers will be responsible for ensuring that appropriate measures are put in place to meet the standard in subsequent years.

20 It is anticipated that the harvest strategy standard will influence the current fisheries scientific assessment process and the nature of fisheries management advice presented to the Minister of Fisheries. The current status of the stock will need to be assessed relative to the specific standards adopted for the stock. Similarly, management advice will report on current performance of the stock relative to those standards.

Review of Harvest Strategy Standard

21 The Ministry does not envisage that standards will be subject to frequent revision. In order to provide the necessary certainty for planning purposes both for Government and fishers, it is anticipated that as from the date of approval, the harvest strategy standard will be reviewed on a five yearly basis (unless legislative change or other circumstances require earlier review).

22 Reviews will consider developments in international best practice in fisheries management, the effectiveness of the standard in delivering on the obligations in the Fisheries Act 1996 (and as a result; sustainable fisheries), and the implications of the standard on fishing activities and fishers. The effectiveness of the standard will to some extent be dependent upon the nature of the management responses that are actioned. A key performance indicator will be the number of fisheries where significant rebuild strategies have been implemented (including fisheries that are closed).

23 Reviews will seek to address any unanticipated adverse consequences of the application of the standard. For example, if there a significant reduction in economic return from fisheries because the standard has been set too conservatively (or too liberally), the standard may be reviewed to provide a better balance between the sustainability and utilisation objectives under the Act. Similarly, if the standard leads to harvest strategies that do not adequately provide for the interests of recreational and customary fishers, changes to the standard may be made or the need for other policy frameworks may be considered.

24 Before undertaking any review of the harvest strategy standard the Ministry will formally engage with tangata whenua and stakeholders about the criteria to be applied for the purposes of the review.

Terminology

25 The following terms are used in this document.

B_0	A stock's unfished or virgin biomass. It is the average over recent years of the biomass that theoretically would have occurred if the stock had never been fished. It is a stock's theoretical carrying capacity.
B_{MSY}	The average biomass that results from taking an average catch of MSY under various types of harvest strategies.
CPUE	Catch per unit effort is the quantity of fish caught with one standard unit of fishing effort; e.g. the number of fish taken per 1,000 hooks per day or the weight of fish taken per hour of trawling.
$F_{\%SPR}$	The exploitation rate corresponding to a specified percentage of the maximum spawning biomass per recruit. See Appendix IV for further information.
Fishing mortality rates and exploitation rates	The term *fishing mortality rates* is the international currency of the published scientific literature on fisheries management strategies. However, fishing mortality rates are "instantaneous" rates; a mathematical construct. Exploitation rates are the proportion (or percentage) of a stock that is removed by fishing operations during a defined period of time (usually a fishing year). The relationship between fishing mortality rates and exploitation rates is defined in Appendix III. In this document the two terms are used interchangeably to increase transparency for the non-specialist. Mathematicians, who will ultimately be responsible for developing models to assess and implement harvest strategies, should consider reference to exploitation rates to refer to fishing mortality rates.
F_{MSY}	It is the fishing mortality rate that, if applied constantly, would result in the maximum sustainable yield.
M	The natural mortality rate is that part of the total mortality rate applying to a fish population that is caused by predation and other natural events.
MSY	The maximum sustainable yield is the largest long-term average catch that can be taken from a stock under prevailing ecological and environmental conditions. It is the maximum use that a renewable resource can sustain without impairing its renewability through natural growth and reproduction.

PART TWO: OVERVIEW OF APPROACH

26 The Ministry's overall approach to managing stocks under s 13 of the Act is summarised in the table below. A brief explanation follows.

Table 1: Overview of Approach

Harvest Strategy	Sustain ability indicator	Product ivity	Target	Threshold	Soft limit	Hard limit
Information rich, med-high TAC variations	Biomass level AND exploitation rate	Low	$\geq B_{MSY}$ (or proxy range of 35-50%B_0) on average, AND $\leq$ 75-100% F_{MSY} (or proxy range of $F_{35\%}$-$F_{50\%}$) [1]	90% B_{MSY} or proxy	50% B_{MSY} or proxy	10% B_0 or 25% of B_{MSY} or proxy target (whichever is the highest)
		Medium	$\geq B_{MSY}$ (or proxy range of 30-45%B_0) on average, AND $\leq$ 75-100% F_{MSY} (or proxy range of $F_{30\%}$-$F_{45\%}$) [1]	80% B_{MSY} or proxy	50% B_{MSY} or proxy	
		High	$\geq B_{MSY}$ (or proxy range of 25-35%B_0) on average, AND $\leq$ 75-100% F_{MSY} (or proxy range of $F_{25\%}$-$F_{35\%}$) [1]	70% B_{MSY} or proxy	50% B_{MSY} or proxy	
Information limited, periodic TAC variations	Catch Per Unit Effort (or equivalent)	Low	A range of historical (or projected) CPUEs that occurred when the stock was believed to be at or near optimal levels, conceptually similar to B_{MSY}	90% of target*	50% of target*	25% of target*
		Medium		80% of target*	50% of target*	
		High		70% of target*	50% of target*	
Information deficient, constant TAC	Average catch (evaluate over entire catch history)	Low	(1-M)*average landings over an appropriate period [2]	80% of target*	40% of target*	25% of target*
		Medium		70% of target*	40% of target*	
		High		60% of target*	40% of target*	

* or proxy for B_{MSY} if the target has deliberately been set higher than B_{MSY} and a credible proxy for B_{MSY} can be estimated

1. See Appendix IV for an explanation of $F_{\%}$ levels. Note that the proxy ranges of, for example, 35-50% B_0 and $F_{35\%-50\%}$ are not usually equivalent because the relationship between the two depends on the stock recruitment relationships (see Mace 1994). Therefore, estimated or inferred stock-recruitment relationships should be taken into account when selecting proxies from these ranges.

2. This is a generalisation of the guidelines in the "Guidelines to Biological Reference Points for 2005-06 Fishery Assessment Meetings" (Ministry of Fisheries, 2006).

27 Three distinct core harvest strategies are proposed. They provide a tiered approach based on differing information levels for a stock combined with matching harvest rates (i.e. maximising sustainable catch, periodic TAC changes, or constant TAC). The Ministry considers that the harvest rate for a stock should be consistent with the information base available for the stock. The tiered approach acknowledges substantive differences in the availability of information for different stocks. The nature and quality of information will influence the harvest rates deemed to be sustainable. If there is a desire to maximise catch then appropriate information of sufficient certainty and frequency will need to be delivered.

28 A harvest strategy is the combination of measures that determine the time, place, manner, and extent to which a stock is fished. It outlines all of the management tools in place for a stock and how they operate to balance utilisation and sustainability. This includes the actual performance standards for the fishery required by the standards outlined below and the additional management tools such as minimum legal size limits that define the management regime for the fishery.

29 The harvest strategy standard does not seek to guide how the combination of sustainability measures (catch limit, closed areas, mesh size, size limits, etc) may be used to optimise the yield from any given stock. The particular combination of measures will influence the numerical values of F_{MSY} and B_{MSY} for a stock. Nor does the harvest strategy standard address the ideal combination of measures for a stock. The aim of the harvest strategy standard is to guide how appropriate TACs can be best set for a stock in accordance with the obligations set out in s 13.

Component standards

30 Each of the three harvest strategies will consist of a number of component standards. The component standards are the:

a) *Target* – a performance target will be determined for each stock. The target is the desired biomass (i.e. population level) or fishing mortality rate for a stock. The target will be determined foremost by the productivity of the species and will also be influenced by a range of specific variables applicable to the particular stock. A sustainability indicator will be identified which will be used to assess the performance of the fishery relative to the target.

b) *Threshold* – a biomass threshold will be determined for each stock. A threshold triggers a defined management response designed to ensure that the biomass of a stock does not continue to decline below the threshold.

c) *Limits* – one (or possibly two) biomass limits will be determined for each stock. A soft limit will be determined in every instance. A soft limit triggers the implementation of a set of prescriptive measures to halt further decline and to ensure the fastest possible rebuild of the stock, taking into account socio-economic factors. A hard limit may also be adopted. It represents the defined point at which a stock is closed to fishing.

d) *Rebuild strategy* – a rebuild strategy is an agreed set of management interventions implemented to rebuild the stock to its designated biomass target. The interventions will incorporate the following: a rebuild target, a time horizon for the rebuild and a probability of rebuild within the specific time horizon. A stringent rebuild strategy will be required for each stock that has fallen below the soft limit.

e) *Decision rules* - A harvest strategy will include a number of specific decision rules. The decisions rules are designed to provide guidance on the role of targets, thresholds, soft limits, hard limits, and rebuild strategies.

31 The following three diagrams illustrate the approach outlined in Table 1 above. Diagrams for each of the three harvest strategy tiers are provided, incorporating the concepts of fishing mortality and biomass targets, thresholds, soft limits and hard limits.

Harvest strategy tiers

32 The diagrams of the three harvest strategy tiers in conjunction with Table 1 document proposed defaults or baseline approaches that will be applicable in the majority of situations. As such, they form the basis of decision rules for harvest strategies. Alternative approaches may be promoted by tangata whenua and stakeholders. The Ministry considers alternative approaches to be acceptable provided that they deliver a sustainability risk that is not greater than that which would be achieved for the appropriate tier under Table 1 and Figures 1-3.

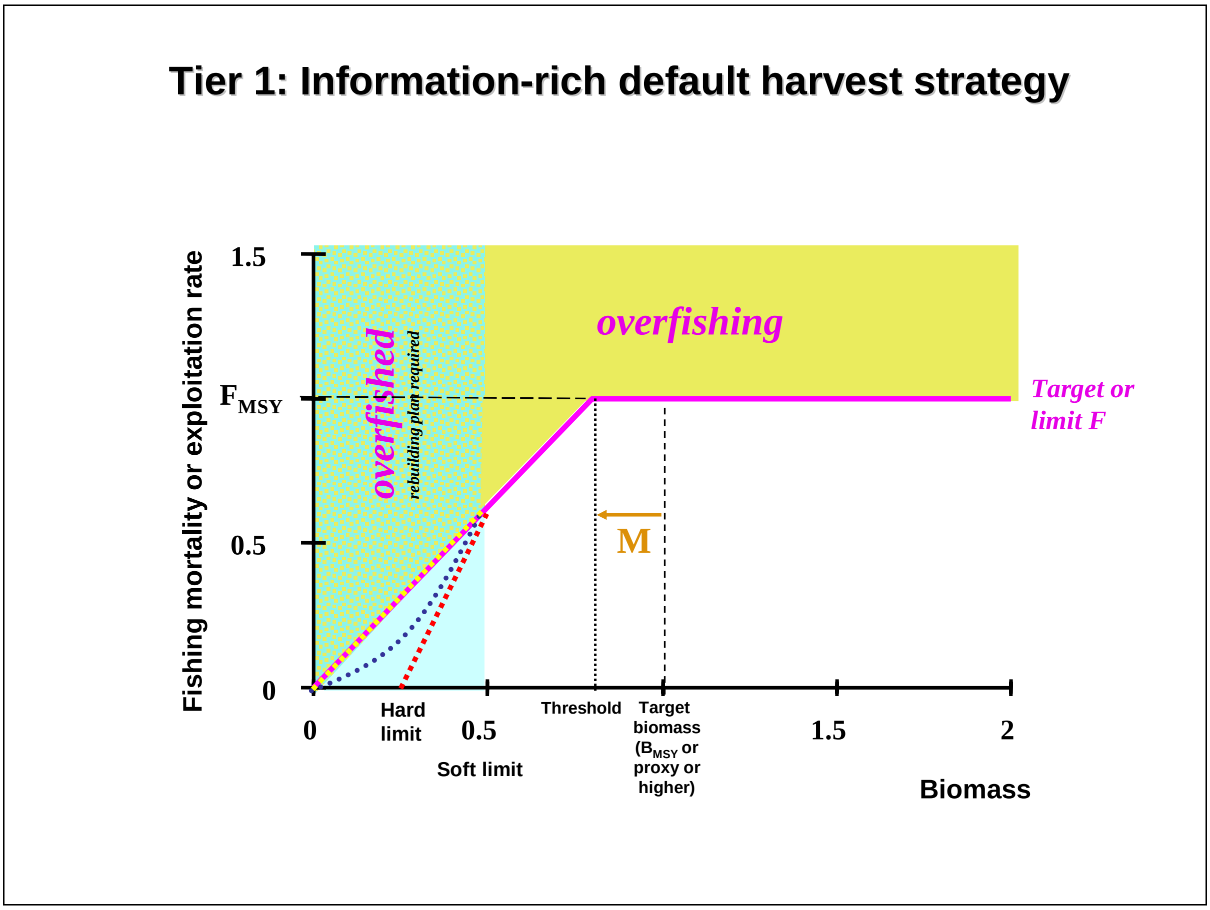

Figure1: Information-rich default harvest strategy. The solid line is the harvest strategy decision rule. For a given recent biomass, it specifies the fishing mortality rate or exploitation rate that should be used to calculate the TAC. The dotted lines represent different possible management responses when adopting a soft limit or a hard limit.

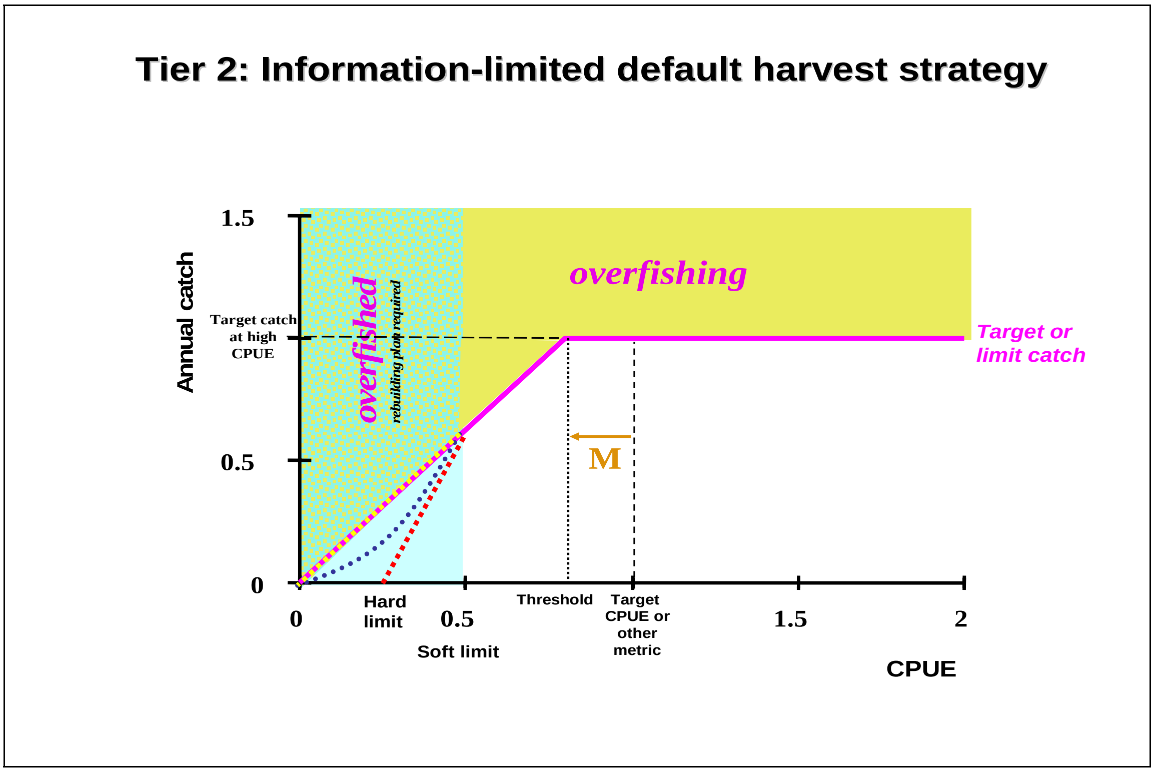

Figure 2: Information-limited default harvest strategy. The solid line is the harvest strategy decision rule. For a given recent CPUE, it specifies the annual catch that should be used as a basis for setting the TAC. The dotted lines represent different possible management responses when adopting a soft limit or a hard limit.

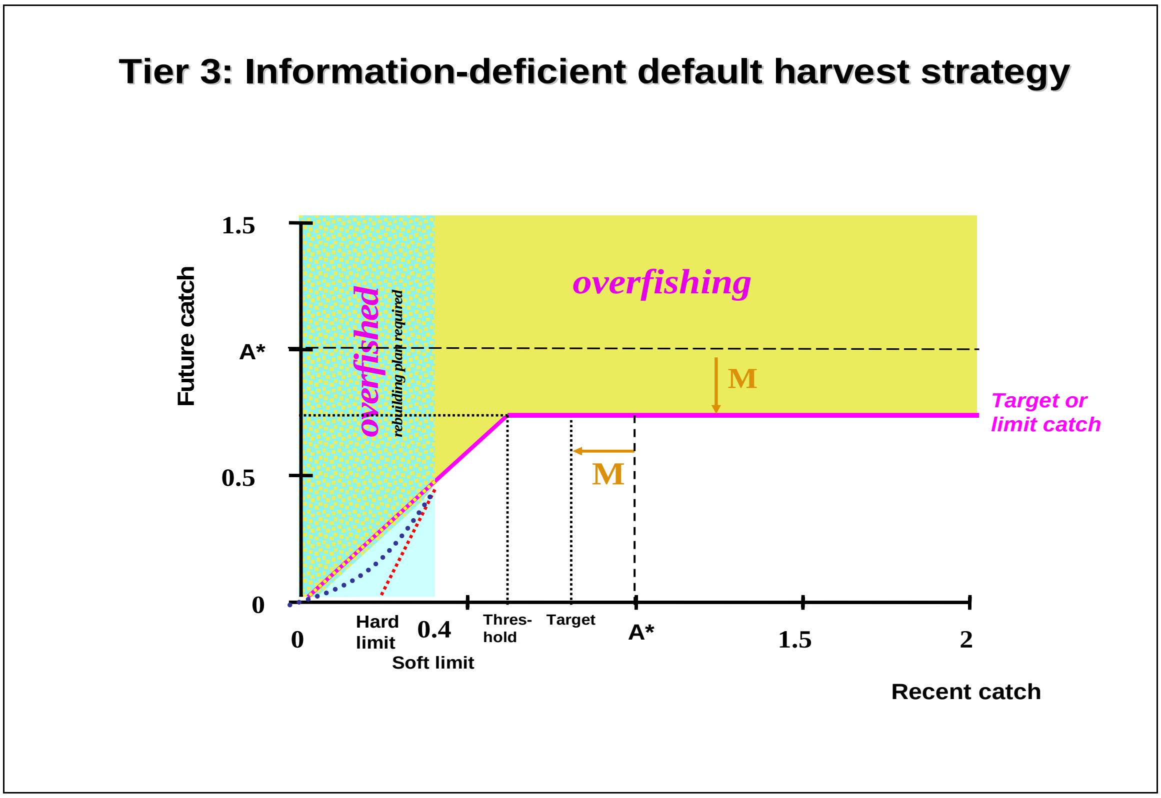

Figure 3: Information-deficient default harvest strategy. The solid line is the harvest strategy decision rule. For a given recent catch, it specifies the annual catch that should be used as a basis for setting the TAC. The dotted lines represent different possible management responses when adopting a soft limit or a hard limit.
A* is the average catch over an appropriate period when the stock is believed to have been at about 40-50% of its unfished level. An important distinction needs to be made between landings and catch (=landings + discards and other sources of mortality).

33 Under the information-rich harvest strategy tier, if biomass is above the threshold then the fishstock should be harvested at the target fishing mortality rate on average (based on a retrospective five year running average). This will cause the stock to fluctuate around the corresponding biomass target level. If the stock falls below the biomass threshold, fishing mortality should be reduced proportionately to facilitate rebuilding. If the stock falls below a soft limit, stronger management action is required; i.e., formulation of a time-specific, stringent rebuilding plan. If biomass continues to decline, complete closure of the fishery may be required (a hard limit).

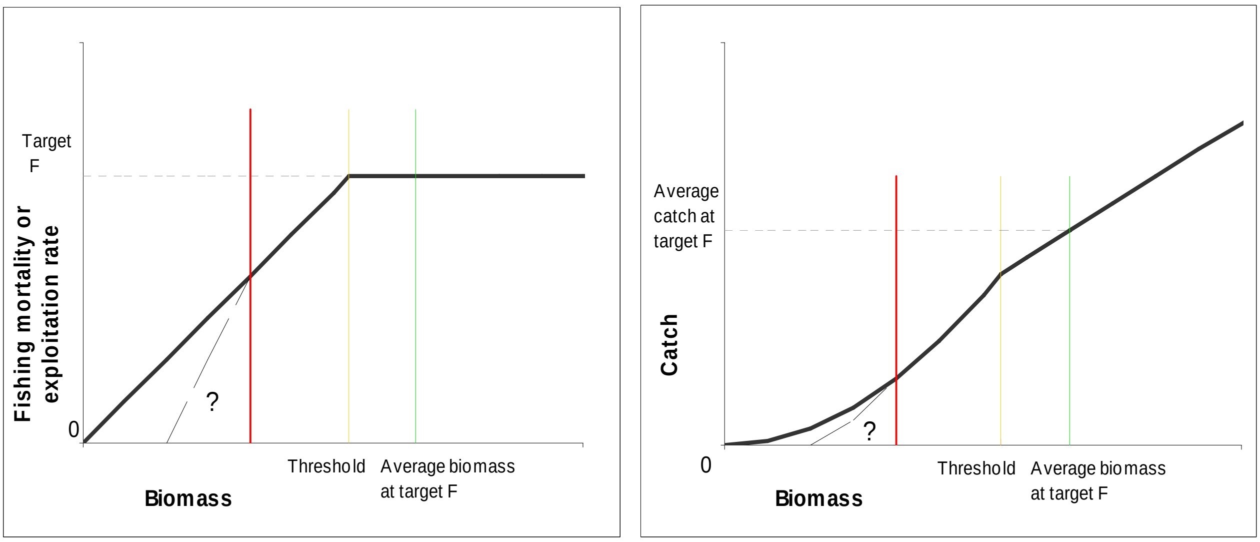

Figure 4: Translation of the Tier 1 harvest strategy into catch levels.
(Note: the solid lines reflect a soft limit approach; the extended dashes reflect a hard limit approach)

34 Another principle is that the less information available for a stock, the more conservative the harvest strategies should be. Superficially, there appears to be little difference between Tiers 1 and 2. However, Figure 4 shows that for Tier 1 stocks future catches can be increased as biomass increases above the target level; for the other two tiers, catches should not increase at high biomass levels. Generally, this can only happen if there is sufficiently reliable data to ensure that estimates of current biomass are robust and that exploitation rates will not exceed F_{MSY} or an equivalent proxy.

How it works

35 Within each of the three information-based harvest strategies, species will be assigned to one of the three productivity bands (high, medium, and low productivity). A number of factors will be used to assess the productivity of each species. As a general rule, the majority of species fall within the medium productivity band (i.e. average productivity for New Zealand fish species). Most shark and deepwater and/or long lived species generally have low productivity. A limited number of New Zealand species have high productivity – most notably forage species (anchovy, pilchards, sardines) and skipjack tuna.

36 The productivity of the species is a key determinant in arriving at the target, threshold, limit, and rebuild strategies for the species. Stocks that are highly productive can as a general rule sustain lower biomass target levels and/or higher levels of exploitation than low productivity stocks. It is also permissible for high productivity stocks to undergo larger fluctuations in terms of biomass

levels before active rebuild measures are required (provided that these stocks are not already depleted). Species with low productivity levels are more susceptible to the risk of overfishing in the sense that they will take longer to rebuild from depleted levels. Hence, higher biomass levels and lower levels of harvests are appropriate, and rebuild measures should be initiated following smaller biomass fluctuations.

37 The desired performance measures for the targets, thresholds and limits are stated as either a range or a single point. Targets are specified as an acceptable range (with the actual point determined by consideration of relevant social, economic, cultural, and environmental factors applicable at the individual stock level), with thresholds and limits being a given proportion of the actual target adopted. However, the lower the biomass, the more biological and ecosystem concerns take precedence over social and economic considerations.

38 The information available for a stock will determine what metric or unit of measure is used to set the target, threshold and limits for the stock. For high information stocks, where possible, targets should be expressed in terms of fishing mortality rates (or exploitation rates) along with biomass levels, and thresholds and limits should be expressed in terms of biomass.

39 The majority of QMS stocks fall within either the information limited or information deficient tiers. For these harvest strategies, it is difficult to specify prescribed biomass target levels. As a result, appropriate metrics to set targets, thresholds, and limits include catch per unit effort (CPUE) indices and reference year catch levels. Use of a CPUE assessment tool means that the biomass target will vary considerably based on the characteristics of the individual species and the method of fishing adopted. For example, the desired catch rate for a rock lobster fishery may be distinct from that of a trawl fishery.

40 The biomass thresholds will be set as a percentage of the target. Higher biomass thresholds will be required for low productivity stocks (i.e. less fluctuation from the target is permissible). This is designed to limit the risk of overfishing. Low productivity stocks generally require long rebuild periods and as a result overfishing is to be avoided to the extent possible; hence, intervention needs to occur at an earlier point than with medium and high productivity stocks.

41 As a percentage of the targets, the biomass thresholds at the information deficient tier are generally less restrictive than those at the information rich and information limited tiers. The basic reason is that the available information is likely to be less precise and, as a consequence, it may be difficult to determine when a stock is at, say, 90% of its target. However, the targets themselves should also be set more conservatively for low information stocks compared to high information stocks. The ability to determine reasons for changes in catch rates or catch levels will be problematic. Information rich stocks are few in number and are generally the higher volume and/or value target species.

42 A soft biomass limit is proposed for all stocks under all harvest strategy/information tiers. For the upper two tier information tiers, the soft limit is 50% of the biomass target or 50% of a B_{MSY} proxy if the target is deliberately set higher than B_{MSY} and a credible proxy can be estimated. For the bottom information deficient tier, the soft limit is 40% of the biomass target or 40% of a B_{MSY} proxy if the target is deliberately set higher than B_{MSY} and a credible proxy can be estimated. The soft limit for the information deficient tier is intended to ensure adequate differentiation is made between the threshold and the limits.

43 There is also the potential to adopt a hard biomass limit. No final decision has been made about the adoption of a hard limit in combination with a soft limit for all stocks under all harvest

strategies/information tiers. At this stage, the Ministry has a stated preference for adopting a hard limit in all instances. The hard limit is 25% of the biomass target or 25% of a B_{MSY} proxy if the target is deliberately set higher than B_{MSY} and a credible proxy can be estimated (a slight variation is proposed for the high information tier – see Table 1). When a stock is determined to be at or below the hard limit, the fishery will be closed.

44 Imposing a fishery closure for bycatch stocks may appear overly severe given the impact on higher valued target fisheries. There is the option to explore other management options available under the Fisheries Act 1996, such as actively setting a target below B_{MSY} in order that a target fishery can be maintained. However, there remains a requirement to ensure the sustainability of all stocks, including stocks managed under s 14A. An alternative may be to reduce the catch level of the target stock. Detailed discussion of the use of limits is set out later in this document.

45 It is accepted that there may be high uncertainty regarding whether or not the biomass limit has been attained. A decision rule may be used to define the circumstances in which it is determined that a biomass limit has been breached (for example, using the point estimate of the base case assessment).

46 In terms of rebuild rates, the current practice is that a stock assessment analysis must indicate a greater probability than not that the stock will simply increase in size (by as little as one kilogram) over a specified period of time. This does not represent a "rebuild strategy" in terms of any accepted meaning of the term. In response to this situation the following formal rebuild standard is proposed: where a stock is below the soft limit the stock should be rebuilt to the target within a time period between T_{min} and $2*T_{min}$ (where T_{min} is the estimated median number of years it should take for a stock to rebuild with zero fishing mortality). Under a rebuild strategy, the lower the biomass, the more biological and ecological concerns take precedence over social and economic considerations, and the closer to T_{min} the rebuild timeframe is likely to be.

The change in approach

47 Implementation of the harvest strategy standard will represent a significant change in approach for managing fisheries in New Zealand. It introduces new management concepts – for the first time explicit performance levels for fisheries will be specified in the form of fishing mortality and biomass targets, thresholds, limits, and rebuild rates. In most current instances, existing biomass targets or rebuild rates are implied or very poorly defined and have not been set as the result of any detailed debate with stakeholders.

48 From a fisheries science perspective, greater focus on fishing mortality or exploitation rates is proposed. Fishing mortality reference points are internationally recognised targets and limits in many fisheries. The aim is not to replace or substitute F_{MSY} for B_{MSY}. However, a change of language and underlying approach to assessing fisheries is proposed with the adoption of F_{MSY}. Exploitation rates provide a sounder basis for determining the sustainable catch level at any given point of time. B_{MSY} equates to a long term average biomass level; the actual biomass level fluctuates continually. F_{MSY} takes into account that fluctuation by allowing for a fixed proportion of catch to be taken based on the current biomass level. Absent of significant environmental changes or external events, F_{MSY} functions as a self-correcting mechanism that will enable a stock to rebuild from any biomass level.

49 The benefit of a standards-based approach will be to provide greater certainty and transparency as to the current status of our fisheries against explicit performance measures. It will highlight when management intervention is required to ensure the sustainability of individual

fisheries. It aims to reduce the risk of overfishing, in some fisheries this will mean that a more precautionary approach is taken to setting the TAC. The result of maintaining stocks more frequently at or above the desired target level will provide greater utilisation benefits overall to users of the resource.

50 The imposition of the standard may require significant changes to the current management of various stocks. Not all stocks will meet the standards when they are implemented. More stringent measures are likely to be required for some fisheries, including reductions in catch levels, to ensure that stocks comply with the standard. The scientific assessment process of stocks will undergo changes. The assessments will be required to calculate current stock status relative to targets, thresholds, and limits, and to develop projection models to evaluate alternative rebuilding strategies.

51 The Ministry will adopt a transition period of up to ten years within which changes can be implemented. The transition period recognises that instant changes cannot be made without imposing significant costs on fishers and that for low productivity stocks, in particular, changes need to be implemented over an extended period of time.

52 The core elements of the approach detailed in this paper have been adopted in various countries (e.g. Australia, United States and Canada) and international organizations (e.g. ICES, ICAAT, and the North Atlantic Fisheries Organisation). The concept of multiple information tiers has been adopted in Australia and by the U.S. North Pacific Fisheries Management Council. The adoption of targets, thresholds, and limits reflects international best practice and has been incorporated in harvest control rules and precautionary approach strategies, which have been under development internationally for about ten years. Major rebuild plans have been developed for fisheries in the United States in accordance with legislative requirements. Biological reference points based on fishing mortality rates (or exploitation rates) are now standard components of fisheries management worldwide (albeit not widely adopted in New Zealand to date). It is acknowledged that other approaches do exist, such as management strategy evaluations (MSEs) adopted in Australia and South Africa (where they are known as operational management procedures) and to a lesser extent in New Zealand (e.g. for rock lobster), but these are not necessarily incompatible with the proposed approach. Further information on the international approaches is set out in Appendix I of this document.

53 It is accepted that targets, thresholds, limits, and rebuild strategies can be used in combination in different ways. There is also no single internationally accepted level at which targets, thresholds and limits should be set. Notwithstanding this situation, the harvest strategy standard should be treated as stating a proposed default or baseline approach that sets out what constitutes the minimum acceptable sustainability requirements for all fisheries. The standard equates to the sustainability risk parameters acceptable to Government in implementing the provisions of the Fisheries Act 1996.

54 The harvest strategy standard, given its formal status as a standard and not legislation, does not preclude alternative approaches from being promoted by tangata whenua and stakeholders in particular fisheries. The Ministry considers that as long as they deliver a sustainability risk that is no greater than that which would be achieved by the appropriate default harvest strategy detailed in Table 1 and Figures 1-3, alternative approaches can be adopted.

PART THREE: EXPLANATION

Harvest Strategies

What is a harvest strategy?

55 A harvest strategy is the combination of measures that determine the time, place, manner, and extent to which a stock is fished. It incorporates all of the management tools in place for a stock and how they operate to balance utilisation and sustainability. These include the actual performance standards for the fishery required by the standard outlined in this document and the additional management tools such as minimum legal size limits that define the management regime for the fishery. The purpose of the harvest strategy is to make transparent both the full set of management tools in place in the fishery to achieve the utilisation and sustainability objective(s) specified by the fisheries plan and/or management regime, and how those tools operate.

Three tiers of information levels

56 One of three core harvest strategies should generally be adopted for most fisheries. These are based on the levels of information available:

- Information rich strategies that track biomass fluctuations;
- Information limited strategies designed to detect biomass fluctuations; and
- Information deficient strategies that do not track or detect biomass fluctuations.

57 The harvest strategies operate as a descending hierarchy in terms of information requirements and catch levels provided. Generally, the average catch achieved for a species under an information rich strategy will be greater than that for the same species managed with an information limited or deficient strategy. This is because the degree of uncertainty about what is the sustainable level of harvest is invariably greater where information about a species is poor.

58 This approach best fits with the requirements to maintain or move a stock towards or above B_{MSY}. It is accepted that this approach may not be compatible with the characteristics of, or information levels for, all species or stocks. However, in such instances, the full range of options available in the Act, namely setting an alternative TAC other than based on B_{MSY} (see section 14 of the Act) and managing below B_{MSY} for commercial bycatch stocks (see section 14A) should be utilised (subject to the relevant statutory criteria applicable to these options being met).

Tier One: Information rich strategies

59 The underlying objective of tracking biomass fluctuations is to enable fishers to maximise the available long-term average sustainable yield from a stock. This strategy requires that sufficient information is obtained so that changes in biomass can be reliably tracked. In order to track changes in biomass, regular research programmes and scientific assessments of the status of the stock are required.

60 It is likely that for most information-rich species, a full stock assessment model will be used to track current stock status. The model should provide as a minimum valid estimates of historical biomass, $B_{current}$, B_{MSY}, historical exploitation rates, $F_{current}$ and F_{MSY} (or appropriate proxies for B_{MSY} and F_{MSY}).

61 The biological characteristics of the stock will determine the frequency of the assessments undertaken – low productivity stocks are unlikely to require annual assessments, whereas highly productive, high volume stocks or stocks that are subject to highly variable biomass fluctuations may require more frequent assessments. The current status of the stock, however, may dictate that more frequent assessments are undertaken (particularly if the stock has been determined to be depleted) to ensure that measures taken to rebuild a stock are effective.

62 The key advantage of the approach outlined in this document is that over time fishers will achieve higher catch levels compared to other harvest strategies. Regular tracking of the current biomass level and the fishing mortality rate ensures that the proportion taken annually can be maintained within acceptable limits; hence it reduces the risk of a stock becoming overfished and enables long-term yields to be maximised or nearly maximised.[2] In contrast, infrequent assessments mean that fluctuations both above and below the desired biomass target level are not readily detected, or acted upon, to either preclude overfishing or to make the excess biomass available to fishers.

63 The main disadvantage of an information rich harvest strategy is the frequency of the information required to manage under this approach and the cost of obtaining the information. In some instances the cost of the information may be considered too high compared to the additional catch able to be obtained, even when it is considered as a long term average. This may result in fishers selecting an alternative harvest strategy.

Tier Two: Information limited strategies

64 Information limited strategies enable fluctuations in biomass to be detected, but do not necessarily result in the extent of the fluctuation being able to be reliably determined. The objective of an information limited strategy is to detect positive or negative changes in biomass on a periodic basis.

65 In order to detect changes in biomass, some form of relative biomass indices should be used. The information available is unlikely to enable B_{MSY} to be calculated. A suitable reference point should be adopted as a proxy for B_{MSY}.

66 The key advantage of this approach is that the risk of overfishing can be monitored. The strategy may provide a lower cost option for fisheries of a limited nature (by value or volume) that cannot sustain an information rich harvest strategy in terms of cost-effectiveness.

67 The disadvantage is that some catch will be foregone, compared to a high information strategy for the stock, as a result of less frequent reviews of the stock, more limited information available and, consequently, a reduced ability to take advantage of high biomass levels.

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[2] From a practical point of view, this type of strategy produces long term yields that are near the maximum. The true maximum is often a purely theoretical concept (achieved, for example, by restricting catch to a single age class), that is not achievable in practice.

Tier Three: Information deficient strategies

68 Information deficient strategies do not readily detect changes in relative biomass levels and do not seek to maximise long-term average catch levels. These strategies seek to maintain a relatively constant catch level from the fishery. A change in the TAC will likely occur only if there is a sharp change in the level of catch that has been taken for some period of time.

69 Under an information deficient strategy there is likely to be significant uncertainty about what represents a sustainable level of catch, particularly in the absence of any ability to assess biomass reference points or yield levels. As a result, the catch level set must be significantly discounted compared to that set for the same stock under an information rich or an information limited harvest strategy.

70 Even for an information deficient strategy, the risk of a stock becoming overfished must be minimised to the extent possible. It should also deliver some degree of certainty to fishers about the level of catch likely to be provided.

71 Adoption of this strategy for a stock may lead to a significant reduction in long-term average catch levels in order, primarily, to manage the risk of overfishing. A constant catch strategy is inherently risky. It may lead to catch levels being set at an unsustainable level when the biomass fluctuates significantly below B_{MSY}. In such circumstances, maintaining a constant catch is likely to result in further decline of the stock and lead to a high risk of stock collapse.

72 Management under an information deficient strategy will also be problematic because of difficulties in ascertaining the extent of changes in the current size of the population. A significant change in catch levels may be the result of a change in fishing practice rather than a change in abundance of the information deficient stock.

Key Inputs to Standard

73 The individual components (target, threshold, soft and hard limits, and a rebuild strategy) will recognise a combination of four key variables:

a) The productivity characteristics of the species: life history characteristics render some species more susceptible than others to overfishing;

b) The nature and extent of utilisation of the resource: use values will vary between species and between fishing sectors. Use values reflected by volume and value (social, cultural, and economic) need to be recognized;

c) The state of knowledge about a fishery: the extent and frequency of new information about a stock can operate to either mitigate or aggravate the risk profile for a stock. It is clear that we will never have complete information about all species, including those in the QMS due to the cost-effectiveness of obtaining such information. However, in the absence of complete information, the objective is to ensure that the sustainability risk and utilisation opportunity is addressed appropriately; and

d) The ecosystem impacts of fishing for the resource: the fishing methods employed to catch the species will have various impacts on the aquatic environment, including effects on non-target commercial species, protected species and marine habitats. These relationships will influence the risk profile associated with fishing specific species.

74 The four key elements establish a profile for a species that can be used to set a target, threshold, soft limit, hard limit, and rebuild strategy. The productivity variables create a basic risk profile. A species is categorised into one of three productivity bands – low, medium, and high productivity. The productivity bands establish clear sustainability constraints. The utilization, information, and ecosystem factors provide an additional risk and opportunity assessment that determines the actual performance measure at the individual stock or quota management area level within the allowable range provided within the productivity bands (i.e. they could aggravate or mitigate the degree of risk).

Productivity bands

75 It is acknowledged that there is no one fixed target point for a stock, or that there is a single target point which is applicable to all stocks. Target fishing mortality rates (or, equivalently, target exploitation rates) generally range from $F_{20\%}$ to $F_{55\%}$ - that is fishing mortalities corresponding to 20-55% of the maximum spawning biomass per recruit. The target point is a direct function of the characteristics of the species and harvest strategy adopted. The combination of the four key variables (biological, use, information, and ecosystem considerations) can be used to determine where the target for the stock is on the continuum.

76 Rather than seeking to assign targets for all possible combinations, it is more appropriate to group the possible options into three basic categories or bands. The same categorisation is equally relevant to the assessment of targets, thresholds, limits and rebuild strategies. As a result, the use of productivity bands (low, medium, high) is preferred rather than making individual decisions for each stock on a broad continuum without any predetermined parameters or reference points. Therefore, for each of the productivity bands an acceptable range is specified. The fishery specific factors influence the final outcome. For example, even though individual ling stocks (or management areas) may have the same productivity characteristics, they may differ from one another based on economic value and research level.

77 The categorisation of species on a productivity basis provides a strong sustainability focus to the standard setting process. Two approaches could be adopted in terms of categorising species – either from a sustainability or utilisation/value perspective. While it is accepted that fishing is about utilisation of the resource and that utilisation constrains sustainability, and vice versa, it is proposed that the categorisation is governed primarily by sustainability concerns. The rationale for the productivity variables determining the band reflects the basic premise that sustainability concerns should not, as a general rule, be overridden by utilisation values.

78 In terms of how the accepted target range works, two potential starting points have been identified. One option is that the default presumption at the conservative end of the band is adopted as a starting point for all species subject to a deduction for relevant mitigating factors (utilisation/value and information variables). Hence, if there is no research or the research results are highly uncertain then the target remains at the conservative end of the band. The second option is to adopt the middle of the band as the default position, with use values and information variables then influencing the final placement on the band. These variables can act both as mitigating and aggravating (or limiting) factors. The Ministry proposes to adopt the second option as it enables a more appropriate balance between use and sustainability values.

79 As a policy tool, the use of bands and defined performance ranges is a common device. It provides a degree of both consistency and flexibility in assessment and decision making. There is a degree of discretion as to how a species is categorized and where targets for individual stocks are set. The bands are not designed to fetter decisions or replace the statutory obligations of the

Minister of Fisheries under s 13 of the Fisheries Act 1996, but rather to act as a policy guide for the implementation of those obligations. However, a clear rationale is needed when decisions are made to act outside the bands.

80 The use of productivity bands and the risk and opportunity assessment are consistent with the Minister's statutory obligations under the Fisheries Act 1996. They are designed to ensure sustainability of the resource and address the adverse effects of fishing on the aquatic environment. The bands enable utilisation values to be recognised within appropriate sustainability constraints. The ecosystem considerations are drawn from the obligation in s 13 of the Act to take into account the interdependence of stocks. More broadly, such an approach is consistent with the environmental principles and the overriding intent indicated in the purpose statement of the Act.

Risk and opportunity profile

81 Risk and opportunity profiles consist of assessments of a stock based on a number of variables. The productivity variables determine the band and target range applicable to a species, with the utilisation, information, and ecosystem variables determining the status within that range. The intention is that each stock is assessed based on the set of variables that are applicable to the stock.

82 The productivity variables consist of the following:

- Fecundity – the fecundity of a species is a key indicator of the robustness of the species to fishing effort and its ability to rebuild.
- Recruitment – the ability to monitor year class strength makes it easier to take advantage of strong year classes and to guard against overfishing.
- Age at maturity / natural mortality / growth rates – high age at maturity, low natural mortality or slow growth indicate that a stock probably has low resilience to fishing.
- Juvenile fishing mortality – in general, lower average ages of fishing mortality will result in lower estimates of both F_{MSY} and B_{MSY}, and may be sub-optimal from an economic viewpoint.
- Distribution – the extent of the geographical distribution of a species will impact the resilience of the species to fishing.

83 The variables exhibited by the stock determine the relevant band. All variables in any particular risk band must be considered in order to determine the overall risk profile for the stock. Hence, the presence of a single high risk variable does not necessarily place a stock in the high risk band. Note that no weighting of the individual variables is currently proposed.

Table 2: Approximate ranges of life history characteristics that determine productivity categories and risk profiles.

Variable	*Low Productivity/ High Risk*	*Medium Productivity/ Medium Risk*	*High Productivity/ Low Risk*
Fecundity	Low fecundity (fecundity depends on the life history type)	Medium fecundity	High fecundity
Recruitment	Recruitment low or episodic; or unable to estimate incoming year class strength	Recruitment moderately variable; or incoming year class strength can be at least qualitatively estimated	Recruitment relatively steady; or incoming year class strength well estimated
Age/Growth rates	Age at maturity 15+ years	Age at maturity 7-15 years	Age at maturity less than 7 years
Juvenile mortality	High levels of catch of juveniles	Moderate catch of juveniles	Limited or no catch of juveniles
Natural mortality (M)	Less than 0.1	0.1-0.2	Greater than 0.2
Distribution	Single location or isolated populations	Multiple locations	Widely dispersed across EEZ or number of areas

84 An appropriate combination of these variables leads to an overall determination of the productivity band applicable to the stock. It is proposed that any additional biological factors not incorporated in the relevant stock assessment model should be treated as mitigating or aggravating factors.

85 A secondary set of variables relate to the identification of the target within the relevant band. These consist of:

Utilisation variables

- fishing sectors – the participation of one or more fishing sectors will influence the different use values that should be reflected in management measures. High levels of non-commercial interest in a species (commonly referred to as a "shared fishery") may result in an objective to increase the availability of larger-sized fish – hence, the ability to set a target biomass below the default starting point within the band may be constrained (or a target at the higher end of the band may be adopted).
- fishing practices - the susceptibility of particular stocks to overfishing may be increased by the targeting of aggregating species. Species that do not aggregate are rarely fished commercially but fishing of highly concentrated aggregations often results in very clean fisheries with limited bycatch. However, the assessment method and aggregating nature of a stock may produce an aggravating risk factor. For example, CPUE based assessments could provide an overestimate of the available biomass; hence increasing the risk of overfishing.
- economic value – the economic value of the fishery overall will be assessed. The species/stock may have importance as either a target or bycatch species.

Information variables

- primary information sources and assessment method – different weightings may be applied to fishery dependent and fishery independent information sources based on an assessment of the reliability, adequacy, and certainty of the information and assessment method. For example, greater weight may be placed on a modelled assessment than a CPUE index alone.

The outcome for a high risk stock is that the use of an assessment with tight confidence intervals may necessitate a lower biomass target level within the band to be set.

- frequency of information – the degree of risk mitigation can be enhanced by the frequency upon which the information for a stock is updated. The level of investment to obtain additional information should be balanced against the utilisation opportunities that result.

Environmental variables

- trophic relationships – the role of a species as a key prey or predator species in its ecosystem needs to be considered.
- protected species – the fishing method may have particular adverse effects on protected species.
- vulnerable habitat/biodiversity – fishing in a particular location may have particular adverse effects on the aquatic environment.
- species assemblages – the fishing of a mixed species fishery may exacerbate the risk of overfishing one or more stocks. The particular target adopted for those stocks (be it a QMS target or a target above long term viability for non-QMS stocks) will influence the target adopted for other stock(s) in the species assemblage.

  (Note, the Fisheries Act 1996 refers to the need to take into account the interdependence of stocks. This factor is incorporated in consideration of trophic relationships and species assemblages.)

86 An assessment of these variables is used to determine the point on the continuum within the defined range. The utilisation, information, and environmental variables can act as either aggravating (limiting) or mitigating factors. The relative strength of the aggravating or mitigating factors will determine the extent of departure from the default starting point within the band. No hierarchy or weighting of the different variables is proposed. The utilisation and information variables also reflect the objective in the purpose statement of the Act of enabling people to provide for their social, economic and cultural well-being.

87 It is widely accepted that seeking to maintain all interrelated or individual stocks in a species assemblage at the target level of B_{MSY} is not feasible from a biological or fisheries management perspective. Certainly that would be the case if a single biomass target was adopted for all stocks. However, it is accepted that in some instances, especially given the intention to set more cautious catch limits for the two lower information tiers, there will be situations where targets for certain species in a mixed species fishery may act as a limiting factor by constraining the exploitation of associated species. This may result in the biomass target for a particular species being set above B_{MSY} to ensure associated QMS species in a species assemblage are not overfished and are maintained on average at the specified target level. The Act contemplates that a TAC can be set that enables stock levels to be moved to, or maintained at, a level at or above B_{MSY}, having regard to the interdependence of stocks. An alternative in such situations may be for bycatch stocks to be managed under s 14B of the Act.

Targets

What is a target?

88 A target is the desired biomass level or exploitation rate for a stock. Fish populations fluctuate in size even in the absence of any fishing. With any harvest strategy the biomass will continually fluctuate. The average level around which we should expect the biomass to fluctuate constitutes the biomass target.

89 There is no single target level applicable for all species and stocks. The targets chosen for individual stocks will vary based on the biological characteristics of the stock and the harvest strategy adopted. The target for all stocks must be consistent with the legislative obligations outlined in section 13 of the Act to maintain stocks at or above a level that can produce the MSY.

Setting the target

90 Section 13 is prescriptive in nature. The TAC that is set must either:

a) maintain a stock at a level at or above B_{MSY}, having regard to the interdependence of stocks; or

b) where the stock is at a level below B_{MSY}, restore the stock to a level at or above B_{MSY}, in a way and rate that has regard to the interdependence of stocks, and within a period appropriate to the stock that has regard to the biological characteristics of the stock, and any environmental conditions affecting the stock; or

c) where the stock is at a level above B_{MSY}, alter the stock in a way and rate to a level at or above B_{MSY}, having regard to the interdependence of stocks.

91 In practical terms, there is neither the resources nor information available, nor is it necessarily cost-effective, to ascertain the level that can produce MSY for every management unit in the QMS. In the absence of complete information about a stock there is still a requirement to manage stocks consistently with the approach outlined in section 13. As a result, the harvest strategy standard is required to manage in terms of B_{MSY} and equivalent proxies.

92 The target adopted for a stock is dependent upon the type of information available. The extent of available information covers the full spectrum from catch data alone through to complex stock assessment models. There are a number of metrics that can be used as proxies for MSY-related reference points; these include $\%B_0$, F_{MAX}, $F_{0.1}$, F=M, or the exploitation rate equivalents of the latter. Which of these proxies is used depends primarily on the nature of the information that is available for each fish stock. This information will also influence the types of thresholds and limits that can be adopted.

Setting the target for the information rich tier

93 At the high information end of the spectrum, the required minimum standard is that F_{MSY} or appropriate proxies (e.g. F_{MAX}, $F_{0.1}$, $F_{\%SPR}$ and F=M)[3] must be estimated where it is possible to do so based on the available information. F_{MSY} is the fishing mortality rate that yields maximum average yield or MAY over the long term. F_{MSY} can be thought of as the removal of a constant percentage of the stock during any given year. Fishing a stock at F_{MSY} will by definition move a stock towards B_{MSY} (unless it has become so severely depleted that environmental and biological factors act to keep the stock suppressed).

94 The Ministry considers that use of F_{MSY} is consistent with the intent of s 13 and accepted international fisheries science and management best practice. F_{MSY} should be used in conjunction with B_{MSY} for information rich stocks. Where it is possible to estimate F_{MSY} it will be required as a minimum standard. This does not preclude fisheries managers from identifying a separate target or limit other than an F_{MSY} based target or limit such as a biomass reference year, provided that the alternative is demonstrated as clearly equaling or exceeding the minimum standard in terms of the sustainability risk to a stock, or there are exceptional circumstances that, in a particular case, warrant the standard not being met.

95 The following standards are proposed for information rich stocks:

a) Low productivity stocks –

- $\geq B_{MSY}$ (or proxy range of 35-50%B_0) on average, AND
- $\leq$ 75-100% F_{MSY} (e.g. an exploitation rate of the order of about 2-10% of the recruited biomass) or proxy range of $F_{35\%}$-$F_{50\%}$*

b) Medium productivity stocks -

- $\geq B_{MSY}$ (or proxy range of 30-45%B_0) on average, AND
- $\leq$ 75-100% F_{MSY} (e.g. an exploitation rate of the order of about 10-20% of the recruited biomass) or proxy range of $F_{30\%}$-$F_{45\%}$*

c) High productivity stocks -

- $\geq B_{MSY}$ (or proxy range of 30-45%B_0) on average, AND
- $\leq$ 75-100% F_{MSY} (e.g. an exploitation rate of the order of about 20-30% of the recruited biomass) or proxy range of $F_{25\%}$-$F_{35\%}$*

* see Appendix IV for an explanation of these terms.

[3] See Appendix IV for an explanation of F_{MAX}, $F_{0.1}$ and $F_{\%SPR.}$ F=M is the fishing mortality that equates to the natural mortality of the stock. In the past, F=M has sometimes been considered to be a risk averse, low information strategy, but some fisheries scientists are now recommending even lower levels as default targets; e.g. Walters and Parma (1996) have advocated 0.6 M as a target.

96 The target fishing mortality rate of ≤ 75-100% F_{MSY} represents a proportion of the current recruited biomass level (i.e. the part of the population vulnerable to exploitation by fishing). While the target may appear to be the same for all stocks (≤ 75-100% F_{MSY}), it equates to a different proportion of the current biomass based on the actual productivity of the individual species. Hence, for low productivity stocks the target exploitation rate is much lower than it is for high productivity stocks.

97 The proxy fishing mortality rate relates to the spawning stock biomass (the total weight of all fish in the population which contribute to reproduction). Target fishing mortality rates are calculated based on spawning biomass per recruit analyses – which is essentially the mature fish that are left over after fishing has taken place (see Appendix IV). The same basic principle outlined in the previous paragraph applies here in that lower fishing mortality targets (and hence higher biomass targets) are used for low productivity species, leaving more fishing in the water after fishing as a proportion of the current biomass compared to high productivity stocks. The proxy alternatives are to be used when MSY-based reference points cannot be estimated or are not considered reliable.

98 Using a range of ≤ 75-100% F_{MSY} implies that F_{MSY} is being treated as a limit. There are several reasons why the Ministry has chosen this approach:

a) Section 13 of the Act requires stocks to be maintained, or moved towards, a level at or above that which can produce MSY. One interpretation of this concept, taking account of the dynamic nature of fish stocks, is that F_{MSY} should be a limit, and target fishing mortality rates should generally be somewhat lower than F_{MSY}.

b) Globally, MSY-based targets are frequently exceeded, with the cumulative result that stocks have become overfished.

c) Fishing at or below F_{MSY} ensures that the risk of overfishing is mitigated and reduces the risk of a depleted stock becoming depleted even further.

d) In the long term, fishing somewhat below F_{MSY} results in a small loss in average catch, for a relatively large gain in average biomass; for example, Restrepo et al. (1998) examined the effects of fishing at 75% F_{MSY} for 600 different life history combinations and found that, over all combinations, this resulted in yields of 94-98% MSY and biomass levels of 125-131% B_{MSY}.

e) Simple equilibrium bioeconomic models indicate that F_{MEY} (the fishing mortality rate associated with Maximum Economic Yield) is less than F_{MSY}.

f) Several studies have suggested that ensuring no stock is fished harder than the single-species F_{MSY} is a good first step towards ecosystem-based fisheries management.

g) Treating F_{MSY} as a limit conforms with the precautionary approach and various UN agreements, most notably Annex II of the United Nations Fish Stocks Agreement (a copy is appended to this document as Appendix II).

99 No prescribed standard is proposed in terms of application of (or weighting assigned to) specific aggravating and mitigation factors. The degree of departure from the starting point of the middle of the band is based on the individual assessment of the relevant variables.

Setting the target for the information limited tier

100 In the absence of information to estimate MSY-based reference points, targets will be expressed as $F_{\%SPR}$, $\%B_0$, CPUE-based indices or other appropriate proxy. Separate target ranges will apply for high, medium, and low productivity stocks.

101 It is not possible to identify the ideal targets for each type of potential proxy. There is no single ideal target or target range for every stock. CPUE levels vary considerably based on the type of species and fishing method employed, as does the extent to which CPUE indexes stock size. Nonetheless, the objective will be to identity an ideal target range based on the productivity band for the individual stock. The ideal target range will represent historical (or projected) CPUEs that occurred when the stock was considered to be at or near optimal levels (a level conceptually similar to B_{MSY}). Evaluation of the target range will take into account the exploitation rate or fishing effort time series, the prevailing management regime, the behaviour of the catch time series, and the lifespan of the species. Because the likelihood of a close correlation between biomass and CPUE varies between fisheries, reliance on a period of optimal CPUE levels alone may not necessarily represent an ideal target as it may have resulted in the stock being overfished. Consideration of the levels of aggravating and mitigation factors will determine the degree of variation of the starting point of the middle of the range.

Setting the target for the information deficient tier

102 At the lowest end of the information spectrum, the information deficient fisheries, only catch data may be available. The practice to date for many of the stocks that fall within this category has been to set a TAC based on reported landings. The TACs have as a general rule remained unchanged since they were set. The deficiency of the information available makes it impracticable, and in some cases impossible, to ascertain whether the TAC that has been set will maintain the stock, or move the stock towards, a level at or above that which can produce MSY.

103 A constant catch strategy is an extremely risk-prone strategy unless the catch level has been set very conservatively. For established fisheries with catch records dating back several decades, information may indicate limited variations in catch levels and hence imply that the TAC which has been set is sustainable. However, over an extended timeframe stock abundance will fluctuate, sometimes markedly. A constant catch strategy may result in the stock being overfished, exacerbating any natural decline in abundance. This risk is compounded when managing in an information deficient situation. There is also the risk that reported landings may not accurately reflect the actual level of fishing mortality. For low value bycatch species, an unspecified and unknown quantity may not be landed or reported as being caught.

104 Caution, therefore, should be exercised when setting TACs based on report landings alone. Landings are not, of themselves, necessarily a reliable indicator of current or long term stock abundance. Accordingly, the following standard is proposed for information deficient stocks:

> target set at (1-M) times average reporting landings for a defined period of years. (M is the natural mortality rate.)
>
> (This is essentially a generalisation of the recommendation outlined in the "Guide to Biological Reference Points for 2005-2006 fishery assessment meetings" (Ministry of Fisheries, 2006)).

105 Reported landings of stocks may vary considerably over a number of years. The reason for this may not be due to trends in abundance; rather, it may reflect the fishing practices adopted (i.e. fishing location and gear type used) or the TAC set for the primary target species. It is also acknowledged that setting overly cautious TACs may constrain utilisation unnecessarily and impose significant economic costs on commercial fishers (i.e. result in fishers incurring deemed value payments).

106 In setting the target, no specified set of catch history years is proposed due to the high degree of variability between species and fishing practices. As a minimum the entire period of catch history should be considered. The period chosen to perform the averaging will depend on the fishing mortality or fishing effort time series, the prevailing management regime, the behaviour of the catch time series, and the lifespan of the species. It is desirable that the period be equal to at least half the expected life span of the fish, but this may not always be possible.

107 In order to balance the risk of overfishing while providing for utilisation based on a constant catch information-deficient harvest strategy, the discount rate for setting TACs should be greater for high productivity stocks than for medium and low productivity stocks. The extent to which stocks fluctuate is generally related to their rate of natural morality (M). Stocks with high M have fewer age classes and therefore variation in incoming recruitment tends to result in larger fluctuations in overall stock size. In other words, stocks with higher M generally have larger fluctuations in biomass. They are therefore more likely to fluctuate to dangerously low levels, especially if they are not closely monitored and/or the harvest strategy is a under a constant catch strategy. This is the reason for using a discount factor of 1-M. The result is that the higher the estimate of M, the lower the percentage of reported landings that is to be adopted as the proxy target for B_{MSY}.

Managing at the target level

108 Fish populations fluctuate in size even in the absence of fishing. Therefore, even if an MSY-based harvest strategy were to be adopted and implemented exactly, biomass would continually fluctuate. B_{MSY} is the average level around which we should expect the biomass to fluctuate when a stock is fished at F_{MSY} (see figure below). The issue is to ascertain the acceptable level of fluctuation.

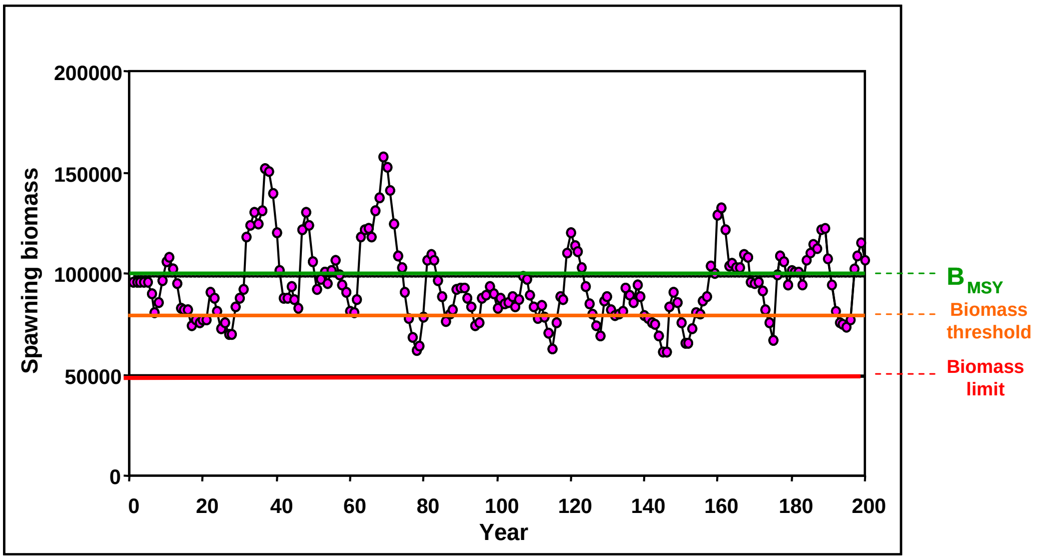

Figure 5: Fluctuations in spawning biomass for a high productivity stock fished at F_{MSY}

109 A decision rule should constrain fishing so as to maintain the stock near or above B_{MSY}, within the range of natural fluctuations. For information rich stocks, the decision rule is that the fishing mortality rate must average F_{MSY} over a defined period of time. The Ministry proposes that the decision rule adopts a retrospective five-year running average. The purpose of using a running average is to avoid overreacting to individual stock assessment estimates and to avoid the need to change exploitation rates or catches every year. The running average would be calculated on a retrospective basis each time an assessment is conducted to determine if the TAC needs to be adjusted. The purpose of the decision rule is to reduce the risk of overfishing. F_{MSY} gives reasonable certainty that overfishing will not occur. Any fishing mortality rate greater than F_{MSY} will constitute overfishing. Overfishing can occur at any biomass level and will ultimately lead to stock decline. The intention is to avoid, wherever possible, the threshold and particularly the limit(s) being triggered.

110 A decision rule based on F_{MSY} is preferred over stipulating an acceptable fluctuation range. Significant debate could arise as to what is an acceptable level of fluctuation. More importantly, the available information is not sufficiently accurate or precise to be able to manage on this basis. A range of plus or minus 10% is well within the margin of error. For modelled stocks, F_{MSY} can be calculated for a defined period of time from the available information. The period of time would be determined by the information cycle applicable to the individual stock. Over that period, fishing mortality could not exceed the aggregate average of F_{MSY}. This would provide some level of flexibility within the period so that TAC changes would not necessarily be required on an annual basis if F_{MSY} was exceeded in any one year. However, where the estimate of F_{MSY} itself changes as a result of an updated assessment, then a TAC change may be required.

111 For information limited or information deficient stocks, a retrospective five year running average is also proposed. For a CPUE proxy, over the five year period the average CPUE figure should not exceed the target CPUE level. Similarly, over the preceding five years, the average reported landings should not exceed the target catch level. This will provide some degree of flexibility for information limited and deficient stocks. A one-off fluctuation will not result in a change to the TAC. The TAC will be reviewed in the event that the retrospective five year average is exceeded. Assessment of the available information may indicate that a TAC increase is warranted, although caution may be required so as not to create an incentive to obtain a higher catch level by consistently overcatching the existing TAC. Similarly some caution is required where the TAC is consistently undercaught. Undercatch of the TAC may not necessarily reflect a decline in abundance.

Threshold

What is a threshold?

112 A threshold level will be determined for each species/stock. A threshold sits between the target and the limit. A threshold is a specified proportion of the average target biomass or exploitation rate or a target CPUE reference point (or other appropriate proxy based on the harvest strategy adopted).

113 The intent of the threshold is to act as a trigger point for a particular level of management intervention. A stock at the level of the threshold indicates that there is a need to modify management measures to guard against further declines in stock size that could ultimately compromise the long term sustainability of the stock and are certainly undermining the attainment of utilisation opportunities (i.e. the ability of the stock to produce MSY or equivalent target) in the short to medium period.

Setting the threshold

114 The actual level at which the threshold is set will be based upon the productivity band applicable to the stock. The same threshold levels are proposed for information-rich and information-limited harvest strategies. Sufficient information needs to be available to ascertain the status of the stock relative to the target. In contrast, less precise information will exist for information-deficient stocks about possible reasons for a decline in reported landings.

Setting the threshold for the information rich tier

115 The following standards are proposed for information rich stocks:

a) Low productivity stocks - threshold set at 90% of the target (using the proxy ranges specified in Table 1 this equates to 31-45% B_0, subject to the actual target selected).

b) Medium productivity stocks – threshold set at 80% of the target (using the proxy ranges specified in Table 1 this equates to 24-36% B_0, subject to the actual target selected).

c) High productivity stocks – threshold set at 70% of the target (using the proxy ranges specified in Table 1 this equates to 17-25% B_0, subject to the actual target selected).

116 The extent to which stocks fluctuate is generally related to their rate of natural morality (M). Stocks with high M have fewer age classes and therefore variation in incoming recruitment tends to

result in larger fluctuations in overall stock size. In other words, stocks with higher M generally have larger fluctuations. In addition, stocks with higher M have higher productivity and, if all else is equal, they are capable of rebuilding faster. Therefore, it makes sense to relate the default thresholds to M. Simulation experiments have suggested that fluctuations in hypothetical stocks that are fished perfectly at F_{MSY} are almost completely in the range of $B_{MSY} \pm M^*B_{MSY}$ for reasonable combinations of life history parameters. This suggests a default threshold of (1-M)* B_{MSY}.

117 Low productivity stocks display a number of attributes that support the threshold level being placed at a relatively high proportion of the target level. Natural fluctuations in stock size are generally lower for low productivity stocks. More importantly, there is a need to avoid lengthy rebuild periods for low productivity stocks, particularly where high use values apply. The aim is to minimise the risk of further stock decline. Hence, rebuild actions should be commenced earlier for low productivity stocks compared to medium and high productivity stocks.

118 The threshold proposed for high productivity stocks may (in some instances) be below the 20% B_0 threshold. Commonly, 20% of B_0 is regarded as a level below which the risk of depensatory effects (commonly called Allee effects in ecological terminology) is exacerbated. When fishstocks become severely depleted, recovery may be inhibited due to environmental effects that are unfavourable to the stock, and/or due to biological effects such as impaired spawning success, competition or predation. In the New Zealand context, 20% of B_0 is the point at which sustainability concerns begin to take precedence over utilisation.

119 In the interval between the target and the threshold, the exploitation rate/level of fishing mortality is maintained, but the total allowable catch declines as the available biomass decreases. Hence, although the percentage of the biomass caught may remain constant, the TAC may be reduced so as to ensure that the stock fluctuates around the target level. In the interval between the threshold and the soft limit, the minimum management intervention is to reduce catch at an accelerated rate if stock biomass continues to decline. A formal rebuild strategy needs to be implemented when the stock falls below the soft limit to enhance the potential and timeframe for rebuild. This could consist of measures such as changes in minimum legal size and closing areas with high levels of juvenile catch rates, as well as reductions in the TAC.

<u>Setting the threshold for the information limited tier</u>

120 The following standards are proposed for information limited stocks:

a) Low productivity stocks - threshold set at 90% of target

b) Medium productivity stocks – threshold set at 80% of target

c) High productivity stocks – threshold set at 70% of target

121 As with the information rich stocks, the thresholds for information limited stocks are based on the underlying resilience of the species, as categorized by the relevant productivity band. In the interval between the target and the threshold, the TAC is reduced when the retrospective five year running average falls below the desired target level. In the interval between the threshold and the soft limit, much more substantial reductions in catch levels should be made. A decision rule may be used to guide the extent of the TAC reductions undertaken.

Setting the threshold for the information deficient tier

122 The following standards are proposed for information deficient stocks:

a) Low productivity stocks - threshold set at 80% of target

b) Medium productivity stocks – threshold set at 65% of target

c) High productivity stocks – threshold set at 50% of target

123 The thresholds for information deficient stocks recognize the difficulty of detecting changes in abundance. Average catch is not a reliable indicator of the status of the stock relative to B_{MSY}. Significant variations in landings can be expected for bycatch stocks.

Limits

What is a limit?

124 A limit represents a point at which further reductions in stock size are likely to lead to an unacceptably high risk of stock collapse and/or current and future utility values are diminished or compromised. It does not represent an extinction threshold – rather it acts as an upper bound on the zone where depensation [4] may occur.

125 There are many documented cases where fish populations have recovered from very low biomass levels. However, it is not something that should be repeated on a regular basis, as it is often not clear what circumstances lead to recovery of stocks and, even for highly productive species (e.g. sardines and herring), recovery has taken as long as 30-40 years, thereby foregoing substantial utilisation opportunities. In some cases, the closure of fisheries or a significant reduction in catch levels has not resulted in the recovery of stocks. There is the potential for climate regime changes to occur, where new species colonise the area or predator/prey relationships are changed to such an extent that stocks are unlikely to recover to previous biomass levels. Hence, limits should be set at levels from which the stock is likely to recover in reasonable time.

126 In the event the stock falls below a biomass limit, a substantive management response is required. Currently, the harvest strategy standard incorporates two types of limits, each consisting of a different form of management response:

a) Soft limit - a time-specific, stringent rebuilding plan, with a very constrained catch limit is to be implemented.

b) Hard limit – the fishery is closed until the stock has rebuilt to the biomass threshold and a rebuild plan is to be implemented.

[4] Depensation is a situation where depleted populations may start to decline at an accelerated rate due to factors such as an inability to find mates, impaired breeding success, competition and predation. In the ecological literature, these effects are commonly called Allee effects.

127 For both limits, the goal is to ensure full rebuild of the stock to the biomass target with an acceptable level of probability. A stock that has been severely depleted is likely to have a distorted age structure (an over-reliance on juvenile fish and few large highly fecund fish). In such instances it is necessary to rebuild both the biomass and the age composition.

128 A key issue is whether or not the harvest strategy should adopt both a hard limit as well as a soft limit. It is proposed that a soft limit will be adopted in every instance. The Ministry considers that there is a definite role for "hard" limits. Based on feedback and further examination of the issue, the Ministry will consider the role of hard limits before finalising the harvest strategy standard.

The soft limit

129 Above the soft limit and below the threshold, fishing mortality (i.e catch levels) will be reduced to support rebuilding. The soft limit is a biomass level that should be avoided due to significantly reduced catch levels (or utilisation values) and the timeframe required to rebuild the stock. Continued decline of the biomass below this level is likely to lead to an unacceptably high risk of stock collapse.

130 The following standards are proposed for soft limits:

a) For information rich stocks - 50% of B_{MSY} or proxy;

b) For information limited stocks - 50% of the target (or proxy for B_{MSY}, if the target has deliberately been set higher than B_{MSY} and a credible proxy for B_{MSY} can be estimated); and

c) For information deficient stocks – 40% of the target (or proxy for B_{MSY}, if the target has deliberately been set higher than B_{MSY} and a credible proxy for B_{MSY} can be estimated).

131 The soft limit explicitly takes into account the situation where the target is deliberately set higher than B_{MSY}. The soft limit for the information deficient tier is set at 40% of the target so as to ensure adequate differentiation is made between the threshold and the soft limit.

132 At or below the soft limit a stringent rebuild plan, time-specific and with a very constrained catch limit, is to be implemented. Further details of the rebuild plan are set out in the following section on "Rebuild Strategies". Ideally, a rebuild plan should be implemented as soon as a soft limit is breached. Experience overseas suggests that a rebuild plan can take some time to develop. As a result, a set of interim measures should be implemented as soon as practicable, until such time as a rebuild plan is actioned.

The hard limit

133 The hard limit is an ecosystem bottom line, the point at which:

- there is a significant risk of stock collapse;
- continued fishing is likely to lead to changes in ecosystem structure and function; and
- there is a risk that a combination of overfishing and adverse environmental change might exacerbate both stock collapse and ecosystems concerns in a multiplicative (synergistic) way.

134 The Ministry considers that there is a definite role for "hard" limits. At some point it will be imperative that a stock is closed to fishing and, to the extent practicable, all catch of the stock is prevented. The Ministry proposes that the hard limit should be set at:

a) For information rich stocks - 10%B_0 or 25% of B_{MSY} or proxy target, whichever is higher

b) For information limited or deficient stocks – 25% of the target (or proxy for B_{MSY}, if the target has deliberately been set higher than B_{MSY} and a credible proxy for B_{MSY} can be estimated).

135 If the hard limit is breached, the fishery will be closed for a designated period of time. It is acknowledged that closure of a fishery will lead to a number of complex, but not necessarily irresolvable, management implications. The threat of a fishery closure will inevitably lead to arguments about whether the stock is slightly above or slightly below the limit – possibly resulting in litigation. Information is often not sufficiently precise to be certain about the current size of a stock. However, this applies in all fisheries when it comes to making decisions about key management measures.

136 The absence of fishing activity means that assessment of the fishery's current status in order to determine when it should be reopened would be problematic, given that assessment of most fisheries depends on information collected during fishing operations. Further issues include how to manage associated target fisheries, and unavoidable bycatch of the stock for which the fishery is supposedly closed.

137 However, if the objective is to maximize the potential for the rebuild to occur and to minimize the risk of collapse then all practicable steps should be taken to ensure the recovery of the stock – i.e. to close the stock to fishing to the extent possible. If the rebuild strategy has not succeeded in halting the continuing decline of the stock, then more stringent measures will be necessary. Fishing would be permitted when a stock is assessed as having rebuilt to the threshold and there is a reasonable probability that the stock will continue to rebuild to the target. The maintenance of the closure is to ensure that the rebuilding of the stock is not transitory in nature and that renewed fishing of the stock will not prevent further rebuild of the stock.

138 An agreed research programme should be implemented to assess the status of the stock – this could consist of research carried out independently of fishing activity, although in many fisheries this may not be feasible given the cost of fisheries independent research and/or lack of viable research alternatives. It would not be unlawful to take unavoidable bycatch; however, it is reasonable that deemed values should be incurred as an incentive for fishers to minimise bycatch.

Fishers taking a species as a bycatch should not be exempt from contributing towards the rebuild of the stock or incurring some of the cost of the rebuild.

139 The closure of a fishery should be an act of last resort. The closure of a fishery is not necessarily inconsistent with the utilisation values recognised in the Act. It is acknowledged that value could still be derived from utilisation of a fishstock at low biomass level. However, the risk to sustainability means that, based on the characteristics of the individual species, the risk to the stock outweighs the benefits of utilisation of a fishstock when it is at the level of the hard limit. Precedents already exist whereby fisheries have been closed in New Zealand.

Mixed species fisheries

140 In a mixed species fishery, the closure of any one stock to fishing will have significant economic implications for fishers targeting other stocks in the fishery. It would either preclude fishing for other healthy stocks or result in significant additional economic costs for commercial fishers due to the requirement to pay deemed values. Under this situation incentives would exist for fishers to take action well in advance of any component of the assemblage breaching a limit reference point. Setting targets for mixed species above B_{MSY} and well below F_{MSY} could provide an additional buffer that minimizes the risk of one species falling below a biomass limit.

141 One potential option is to use a combination of measures based on the individual characteristics of the fishery. For example, single species target fisheries (e.g. most shellfish fisheries) could be completely closed to fishing (i.e. a hard limit). Whereas in a mixed species assemblage, no hard limit would be adopted but once the soft limit was breached for any one species, a rebuilding plan would be developed for the entire assemblage.

142 The ability to enforce particular management measures would be relevant to the option selected. There are limited mechanisms available to effectively preclude the catch of a finfish species by non-commercial fisheries or to apply appropriate disincentives (as in the case of deemed values). Potentially the only effective measure is to close an entire area to non-commercial fishers, rather than seek to prevent catch of a particular species that is below the limit reference point.

Rebuild Strategies

What is a rebuild strategy?

143 If a stock is below B_{MSY}, the Act requires that it be rebuilt back to B_{MSY}. Rebuild strategies need to take account of the characteristics of the individual species/stock in determining the way and the rate at which the stock is rebuilt. A rebuild strategy consists of the rebuild target, the expected timeframe for rebuild and a minimum acceptable probability of achieving the rebuild, together with a set of management interventions that will achieve the desired rebuild.

144 The current practice is that a stock assessment must indicate a greater probability than not that the stock will simply increase in size (potentially by as little as one kilogram) over a specified period of time, usually 3-5 years. This does not represent a "rebuild strategy" in terms of the usual meaning of the term. In response to this situation a formal rebuild standard is proposed.

145 Different management interventions will apply depending upon the status of the stock relative to the target, threshold and soft limit. For example, when the stock size is below the target but above the threshold, a limited number of management interventions may be required. However, where the stock size is below the threshold but above the soft limit, more stringent reductions in

fishing mortality need to be implemented to ensure the stock does not decline further. When the stock is at or below the soft limit, a time-specific, stringent rebuilding plan, with a constrained catch limit is to be implemented.

Management interventions

146 A suite of rebuild actions is proposed as part of the harvest strategy standard. The intent is not to prescribe the actual actions adopted in any one case, but to provide an indication of the range of measures that can be adopted. Notwithstanding, TAC changes based on required reductions in exploitation rates, are considered to be mandatory.

Table 3: Rebuild strategy management interventions

Current Stock Biomass	***Actions Required***
Between target and threshold	Consider TAC changes
	Consider reviewing the frequency and type of data collection, and assessment frequency
Between soft limit and threshold	Proportional reductions in exploitation rate
	TAC changes
	Consider changing regulations on size, method, season, areas
	Consider reviewing the frequency and type of data collection, and assessment frequency
	Consider increasing compliance services
	Consider establishing new indicators for monitoring
At or below soft limit	Consider reviewing the frequency and type of data collection, and assessment frequency
	Develop and implement a stringent rebuilding plan to increase stock biomass at least to the level of B_{MSY} or proxy within the required timeframe
At or below hard limit	Consider establishing new indicators for monitoring
	Implement an agreed research programme
	Set a TAC of 0 tonnes, increase the deemed value rate

147 When the biomass is between the threshold and target, minor adjustments to TACs are expected to be sufficient to maintain the stock so that it fluctuates around the biomass target. By definition, stocks between the threshold and the target do not need rebuilding as long as fishing mortality has not exceeded F_{MSY} (or the stipulated fishing mortality target) on average over a retrospective five year period. An information review may be undertaken to ensure that existing information is adequate to monitor the performance of the stock.

148 Between the soft limit and the threshold a wider array of tools may be employed. A decision may be made to modify existing input controls or introduce new controls. There may be a requirement to increase the frequency of information cycles (e.g. a survey every two years rather than every five years); introduce new information sources if not currently employed (e.g. introduce regular trawl surveys or use observers to collect age and length information); increase compliance coverage; and increase the key indicators monitored (e.g. age and length data). The relative urgency of the situation may mean that decisions are made outside of normal business processes, such as the research planning process.

149 When the stock is at or below the soft limit a time-specific, stringent rebuilding plan, with a constrained catch limit is to be implemented. The array of measures considered would be similar to those mentioned in the previous paragraph. A further significant difference is the requirement to adopt a specific rebuild time frame (as outlined below). In addition, given the depleted state of a stock that is at or below the soft limit, it is anticipated that the actions implemented might consist of more than just a TAC reduction. A rebuild plan should be implemented as soon as a soft limit is breached. In the absence of any pre-prepared rebuild plan, a set of interim measures should be implemented as soon as practicable, until such time as a rebuild plan is actioned.

150 The harvest strategy standard proposes the use of a hard limit, while acknowledging that there may be some debate as to whether it is implemented in every fishery. In circumstances where the stock is at or below the hard limit the option of closing the fishery will be considered. If the stock is a bycatch stock, then all commercial catch will be subject to payment of deemed values. Observer coverage may be required to ensure compliance with this requirement. The fishery is to be closed until the stock has rebuilt to the biomass threshold and a rebuild plan is to be implemented to ensure continued rebuilding to the biomass target. With the hard limit, the requirement to rebuild the stock to the biomass threshold rather than the soft limit before fishing recommences, is that at the level of 10% Bo or 25% of the target (or related proxies) a stock is likely to have a severely distorted age structure. Until the age structure of the population is largely restored, renewed fishing may increase the risk that the stock will be remain in a depleted state.

Timeframes for rebuilding

151 The setting of timeframes for rebuilding a stock must take into account the interdependence of stocks, the biological characteristics of the stock, any environmental conditions affecting the stock and the social, cultural and economic factors relevant to the stock. Another relevant issue is the comprehensiveness and reliability of the available information on these factors and on stock status.

152 At first glance it might seem logical for low productivity stocks to require more stringent rebuild timeframes compared to stocks of medium or high productivity. However, in practice that may not be necessary or practical. Low productivity stocks inevitably have higher $\%B_0$ targets combined with slower growth rates and lower fecundity which means that short rebuild time frames may be unrealistic if the species has been overfished.

153 The Act requires that relevant social, cultural and economic factors be taken into account in deciding upon the way and rate at which a stock is rebuilt to the target level. In the case of stocks with significant allocations to more than one sector (i.e. greater than 20% of the TAC), shorter timeframes might be preferred. Where the stock is virtually exclusively allocated to one sector, the timeframe selected may be more reflective of the interests of the particular sector. For example, industry may prefer a slow rebuild of a stock that maximises the discounted present value.

154 It is proposed that a minimum standard is:

where a stock is at or below the soft limit the stock should be rebuilt to the target within a time period between T_{min} and $2*T_{min}$ (where T_{min} is the estimated median number of years it will take for a stock to rebuild to B_{MSY} or a suitable proxy with zero fishing mortality.

(Note: a mathematical projection model will generally need to be developed to estimate T_{min} and to compare and contrast alternative rebuilding strategies. These will usually be probabilistic models that incorporate uncertainty in the projections. The minimum standard for a rebuilding strategy is that the median of the projected trajectories will result in a biomass of B_{MSY} or suitable proxy being achieved within the timeframe of T_{min} to $2*T_{min}$. This equates to a probability of 50% that the stock will be above/below the B_{MSY} (or proxy) level at the end of the timeframe. However, a stock will not be declared to be rebuilt, and therefore absolved from further rebuilding, until it can be determined that the probability distribution of the estimated biomass is at least evenly distributed around B_{MSY} (or proxy). This means that if the initial rebuilding plan is underachieved/overachieved, it may need to be revised prior to the termination of the timeframe initially set. This may result in a more restrictive/lenient harvest strategy as time progresses.)

155 T_{min} reflects the extent to which a stock has fallen below the target, and the biological characteristics of the stock that limit the rate of rebuild. Allowing a rebuild period up to twice T_{min} allows for some element of socio-economic considerations where complete closure of a fishery could create undue hardships for various fishing sectors and/or the stock is an unavoidable bycatch of another fishery. The probability of rebuild should be increased where the information is highly uncertain or where multiple sectors have significant interests in the fishery.

156 No specific rebuild timeframe is specified for circumstances other than when the stock is at or below the soft limit. Where the fishery is closed to fishing, it is implicit that T_{min} (or a number close to T_{min} where bycatch of the species cannot be avoided) has been adopted.

Decision Rules

157 A harvest strategy will include a number of specific decision rules. The decisions rules are designed to provide guidance about the operation of targets, thresholds, soft limits, hard limits and rebuild strategies. In terms of the target, it is acknowledged that not every fluctuation in stock size will require management intervention – natural fluctuations in stock size are expected. Thresholds should be set near the lower bound of the expected size of the fluctuations. Where the stock is below the threshold, decisions rules may determine the extent of corresponding reductions in the exploitation rate (which will translate into reductions in the TAC). In determining appropriate decision rules, the variables identified for the purposes of determining a target – the productivity, utilisation, information, and environmental variables – constitute useful criteria that should be taken into account.

158 This document does not incorporate all possible decision rules that may be implemented to give effect to the harvest strategy standard in individual fisheries. However, the diagrams of the 3 harvest strategy tiers (Figures 1, 2, and 3), in conjunction with Table 1, document proposed default decision rules that will be applicable in the majority of situations. It is proposed that alternative approaches promoted by tangata whenua and stakeholders may be adopted so long as the alternative meets or exceed the requirements specified. In particular, alternative approaches must deliver a sustainability risk that is no greater than that which would be achieved by the harvest strategies detailed in Table 1 and Figures 1, 2 and 3.

Appendix I: International Context

Notion of MSY

1 The concept of Maximum Sustainable Yield (MSY) was derived in the 1930s. MSY is a biological reference point that relates to both a target biomass level (B_{MSY}) and a target fishing mortality rate (F_{MSY}). The concept was embodied in international law in 1982 in the United Nations Convention on the Law of the Sea. Subsequently, it has been adopted in many national fisheries acts. In New Zealand, this formally occurred in 1996, although MSY-related reference points were used in fisheries assessments well before this date (see the "Guide to Biological Reference Points for 2005-06 Fisheries Assessment Meetings", a version of which has been in Ministry of Fisheries Plenary documents dating from 1988).

2 Despite attacks on its overall applicability in fisheries, MSY has survived as a key biological reference point because it is intuitive (able to be understood by the general public) and operational, and no-one has come up with a superior reference point. It provides a balance or compromise between the competing interests of sustainability and utilisation. Different techniques for estimating MSY have evolved, some of which require relatively few data and some that require considerable data. No other approaches are as universally used or accepted as MSY.

3 It does, however, have some noted limitations. First, there are often estimation problems, although that may in part reflect the reliability of the underlying data, which is a problem for all stock assessment approaches. The suitability of MSY-related reference points as management targets is sometimes challenged. It tends to reflect a single species management approach (i.e. assessing the status of each species individually) that does not readily take into account ecosystem considerations. Certainly non-commercial fishers often consider that a B_{MSY} target results in the available biomass being too low to adequately provide for their interests (although to some extent that can be addressed in New Zealand through setting a target above B_{MSY}). Environmentalists (and others) have advocated that B_{MSY} should be interpreted not as a target but a limit or a minimum.

4 MSY is also seen as being overly constraining in terms of the range of harvest strategies that may be identified for different fisheries. In New Zealand, the Fisheries Act (1996) prescribes rebuilding of stocks that are below the B_{MSY} target or the fishing down of biomass when stocks are above B_{MSY}. It does not allow for a great deal of flexibility. It is also acknowledged that the maximum economic yield for a fishery is invariably different from MSY – in other words the harvest strategy that delivers the optimal financial return to fishers and MSY are not one and the same.

5 Despite these limitations, the scientific and management roles of MSY-based reference points have continued to evolve. The initial view was that MSY was a constant catch that was to be achieved in all years. MSY is now more clearly seen as a long-term average based on a constant fishing mortality rate or other harvest strategy. Rather than being static, natural populations continually fluctuate in size, both with and without fishing activity. As a result, harvest strategies based on MSY-related reference points will generally result in variable annual catches and at any point in time the current biomass will either be below or above the B_{MSY} level. Thus, B_{MSY} must also be thought of as a long-term average.

Harvest Control Rules

6 A relatively recent development in fisheries science is the consideration of a number of biological reference points in addition to biomass targets such as B_{MSY}. In particular, the notion of overfishing *thresholds* and *limits* has become commonplace. These concepts have arisen due to recognition that targets are frequently exceeded (for a multitude of reasons; e.g. uncertainties about data and stock assessments, political and short-term financial considerations, and environmental fluctuations). More risk-averse management strategies have been developed in part because of the ongoing overfishing of many stocks worldwide, but also in response to growing acceptance of the precautionary approach and pressure to incorporate ecosystem considerations into the management of fisheries.

7 Of particular significance is the 1995 United Nations Fish Stocks Agreement. While the agreement relates to the management of populations that straddle more than one national boundary and highly migratory stocks that are found over a wide region, it establishes in international law some key principles that are of wider application. The agreement specifies guidelines for the application of precautionary reference points. The key points are that:

a) Two types of precautionary reference points should be used: conservation, or limit, reference points and management, or target, reference points. Limit reference points set boundaries that are intended to constrain harvesting within safe biological limits within which the stocks can produce maximum sustainable yield. Target reference points are intended to meet management objectives (Annex II, para 2);

b) Fishery management strategies shall ensure that the risk of exceeding limit reference points is very low ... [and] that target reference points are not exceeded on average (Annex II, para 5); and

c) The fishing mortality rate that generates maximum sustainable yield shall be regarded as a minimum standard for limit reference points (Annex II, para 7).

8 International developments in fisheries science have resulted in a proliferation of reference points that have been adopted for different fisheries and in different jurisdictions. Most prevalent are fishing mortality-based reference points (e.g. F_{MSY}, F_{MAX}, $F_{0.1}$, F=M, $F_{REPLACEMENT}$, $F_{EXTINCTION}$, $F_{X\%SPAWNING\ BIOMASS\ PER\ RECRUIT}$ or $F_{X\%SPR}$ (e.g. $F_{20\%}$, $F_{30\%}$, $F_{40\%}$), F_{LIMIT}, $F_{PREC.APPROACH}$, F_{BUF}) and biomass-based reference points (B_{MSY}, 30-60% B_0, B_{LIMIT}, $B_{PREC.APPROACH}$, B_{BUF}). Others include yield-based reference points (e.g. MSY) and recruitment-based reference points.

9 One example of the incorporation of biological reference points into a framework commonly referred to internationally as a harvest control rule, is depicted below. The harvest strategy standard proposed for New Zealand essentially reflects the same basic underlying approach.

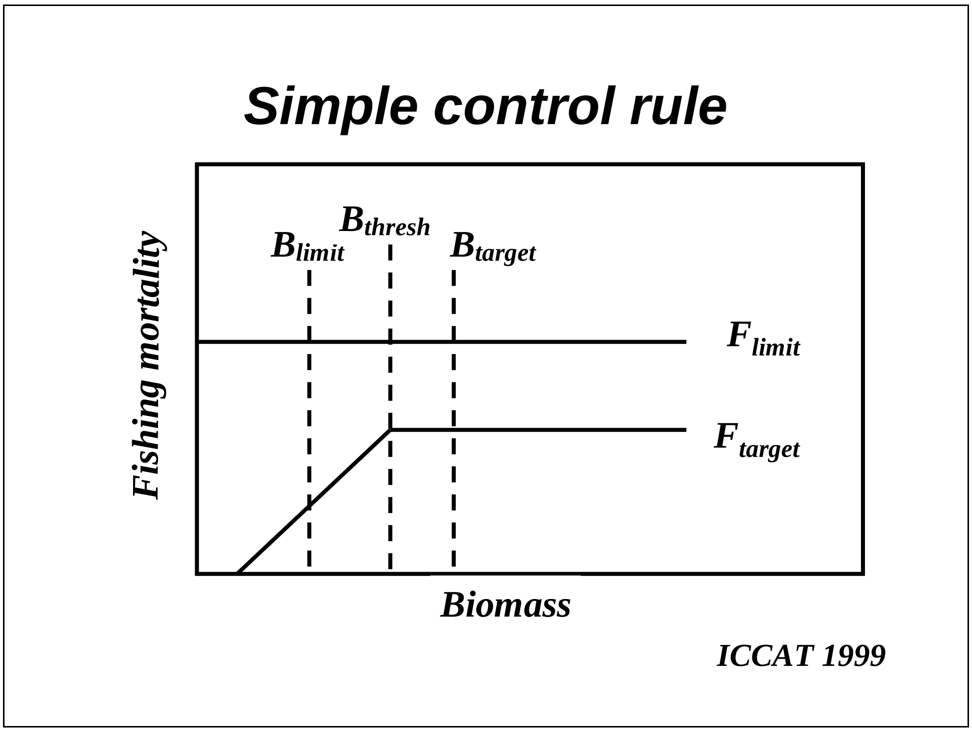

Figure 6: ICCAT harvest control rule

10 The Australia Fisheries Management Authority (AFMA) has implemented an interim harvest strategy policy. The framework of this strategy contains many of the attributes proposed in the current document. Harvest strategies have been designed to meet legislative objectives, and to provide optimum utilisation of resources consistent with Ecologically Sustainable Development (ESD) objectives. The harvest strategies are precautionary in nature. The guiding principles are:

a) A defined limit reference point for the fishing mortality rate (corresponding to 20% of unfished biomass) and target reference point for the fishing mortality rate (corresponding to 40% of unfished biomass);

b) Decreased exploitation rates for low stock sizes;

c) Exploitation rates are decreased as uncertainty about stock size increases;

d) No targeted fishing below the minimum biomass level; and

e) Four fishery tiers, depending on the amount and type of information available to assess stock status.

11 AFMA is also currently developing a more comprehensive Harvest Strategy Policy. Fishery specific harvest strategies consistent with the policy are to be implemented by January 2007.

12 Another variation on the same basic theme is the precautionary approach framework developed by the Northwest Atlantic Fisheries Organisation (NAFO) in 2003. The darker the shade the greater the risk of stock collapse. General actions that would be useful for defining specific harvest control rules in each zone form part of the NAFO framework.

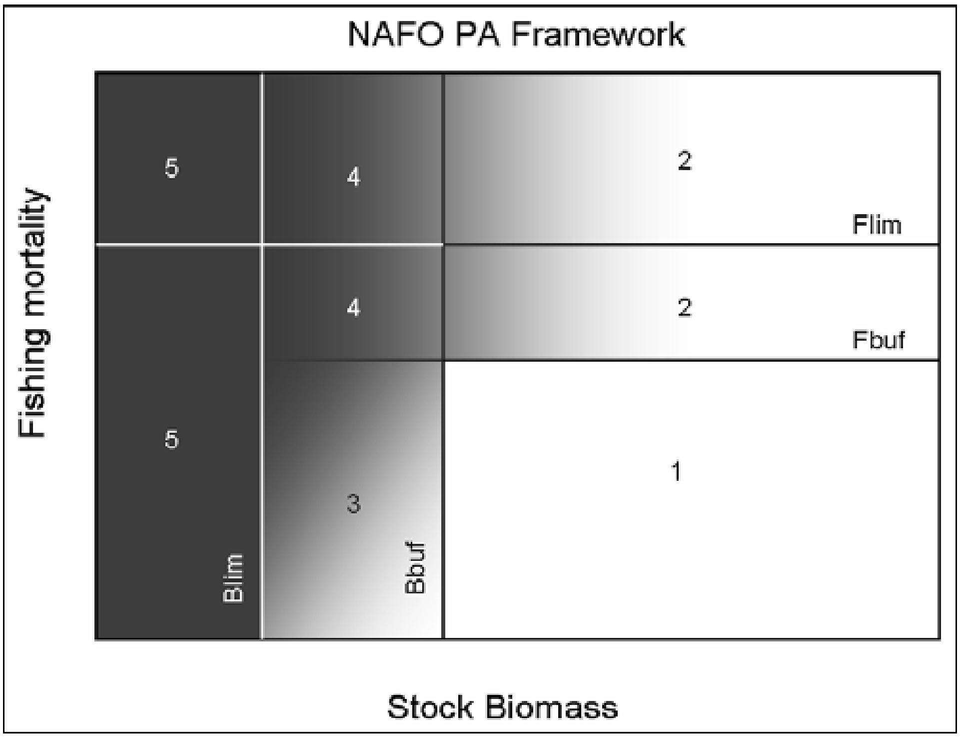

Figure 7: NAFO precautionary approach framework

(1 = Safe Zone, 2 = Overfishing Zone, 3 = Cautionary *F* Zone, 4 = Danger Zone, and 5 = Collapse Zone)

Management Strategies

13 There has also been development of fisheries management strategies that are not necessarily limited solely to MSY-based strategies (generally because of the perceived limitations of such approaches as optimal management objectives). Two such approaches are the ecosystem based fisheries management approach that is being developed by the Department of Fisheries and Oceans (DFO), Canada and the management strategy evaluation (MSE) that has been adopted in some instances in Australia, South Africa and New Zealand.

14 DFO has defined ecosystem-based management (EBM) as "the management of human activities so that ecosystems, their structure (e.g. diversity of species), function (e.g. productivity) and overall environmental marine environmental quality, are maintained at appropriate temporal and spatial scales. EBM recognizes that human activities must be managed in consideration of the interrelationships between organisms, their habitats and the physical environment" (DFO 2004). FAO prefers the term "ecosystem approaches to fisheries" (EAF; FAO 2003). Most if not all, aspects of ecosystem approaches result in management strategies that are more conservative than those developed for single-stock MSY-based approaches (i.e.

they generally result in target fishing mortality rates that are considerably lower than F_{MSY}.

15 Management strategy evaluation, rather than focusing solely on biological reference points, seeks to take into account the robustness of alternative management procedures and socio-economic implications of management decisions. "Management strategy evaluation attempts to model and simulate the whole management process. It makes projections about the state of the fishery resources and other ecosystem parameters for a number of years into the future under a variety of decision-rule options. The management measure and rules that achieve the best results in terms of specified objectives can then be selected and applied. This procedure greatly assists in identifying management strategies that are resilient to uncertainties in scientific understanding. Precautionary management measures and decision rules can be identified by testing the performance of the measure against a range of possible complexities that are likely to be operating in the fishery identified using a selection of appropriate reference points that include acceptable levels of risks" (FAO Technical Guidelines for Responsible Fisheries, No.4, Suppl.2, 2003).

16 The adoption of an MSE has been advocated to provide a framework in which the following issues can be addressed (Campbell, CSIRO Marine Research, 2002):

a) "Decisions being made in the face of high uncertainty about the status, dynamics and future trends of the resources, and similar levels of uncertainty about the social and economic status, dynamics and future behaviour of the fishery or fisheries;

b) Decisions being made in the absence of any long-term strategy and, at best, poorly defined objectives which will usually also be conflicting; and

c) Decisions being made by individuals or groups which are unrepresentative or poorly representative of the full range of interest groups."

17 In South Africa, MSEs (referred to there as operational management procedures) have been implemented since the early 1990s. Procedures are in place for all three of the country's major fisheries. "Butterworth *et al* (1997) describe a management procedure as a set of clearly defined decision rules specifying: i) exactly how the regulatory mechanism, for example a TAC, is to be set, ii) what data are to be collected for this purpose, and iii) exactly how these data are to be analysed and used to this end. This set of rules is to be pre-agreed upon by the parties involved, typically the management agency and the fishing industry. The set of rules is chosen by comparing the anticipated performance of a range of possible sets in terms of agreed performance criteria which would typically include risk to the stock, rewards in the form of catch or profits and the medium to long-term stability of these rewards. Comparison of performance allows explicit consideration of, and agreement upon, trade-offs between conflicting objectives. The anticipated performance is tested by applying the rules to a dynamic model of the resource and fishery, referred to as an operating model. Once agreed to the management procedure should be implemented for a number of years (typically 3 to 5). Thereafter the procedure is reviewed and modified as necessary in the light of any changes in understanding of the resource or fishery that may have occurred in the interim. The revised procedure would then be implemented for the next three to five year period". (Campbell, 2002)

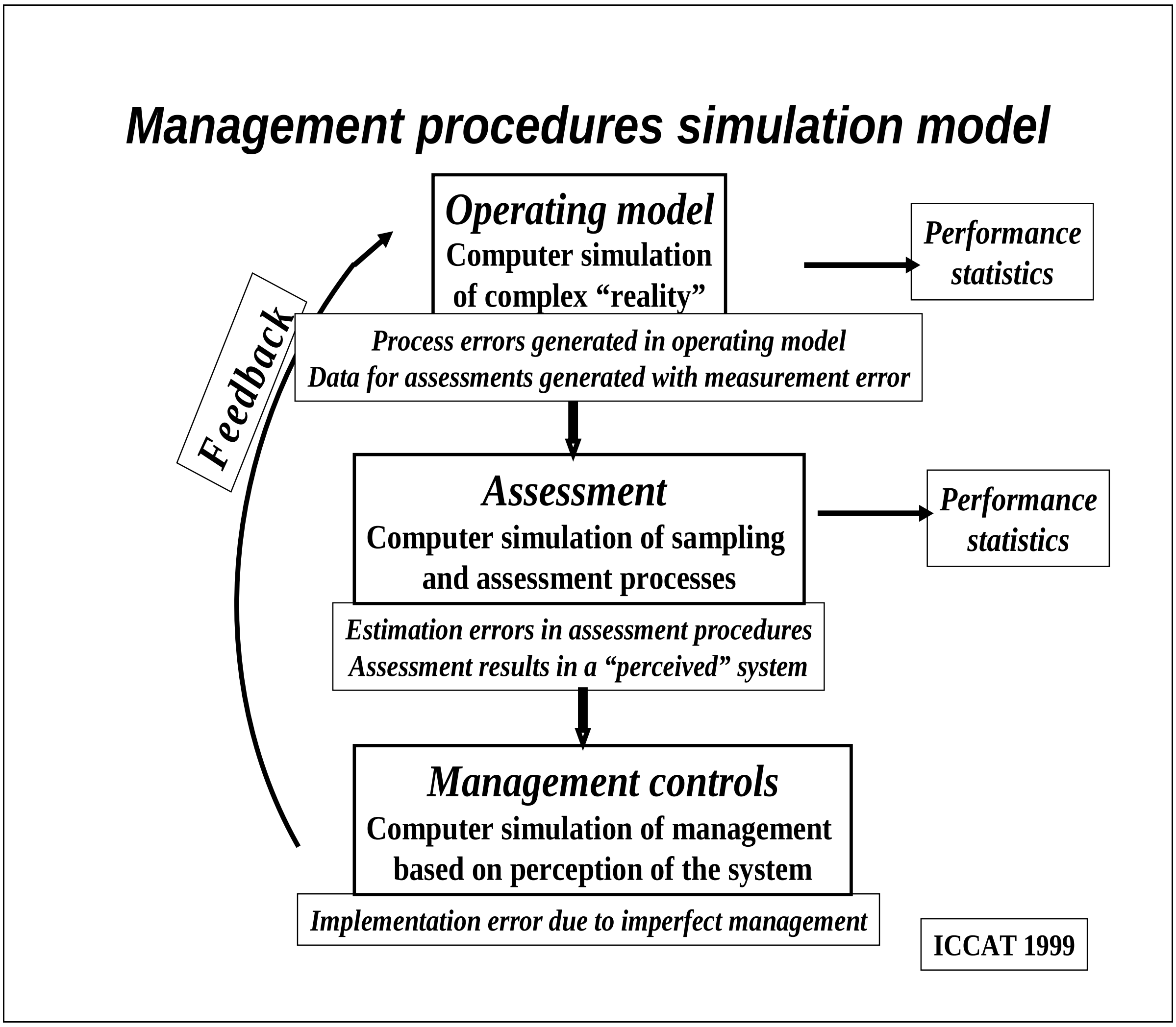

Figure 8: Example of MSE / OMP (ICCAT 1999)

Relationship between Harvest Control Rules and MSEs

18 The outcome of a MSE is a TAC that may or may not incorporate MSY-based reference points for a stock; however, this does not necessarily does not mean that the MSE/OMP approach is inconsistent or incompatible with the proposed harvest strategy standard. The harvest strategy standard does not constrain a MSE from being adopted. An MSE or OMP could be used to assess the target for a stock within the band parameters identified for information rich stocks and as a means of identifying suitable target reference points for information limited and information deficient stocks. It is also possible that an MSE/OMP could devise suitable reference points different from those detailed in the harvest strategy standard.

19 The potential inter-relationship between harvest controls rules and MSEs is reflected in the approach adopted by AFMA. As noted earlier, AFMA has implemented an interim harvest strategy policy. Detailed testing of the harvest strategies is to be carried out through a two year MSE project.

Overall Consistency of New Zealand Approach

20 The New Zealand harvest strategy standard is generally consistent with the overall direction internationally both in terms of fisheries science and fisheries management. The harvest strategy standard adopts target, threshold, and limit biological reference points. It is precautionary in nature in terms of setting targets and responding to the uncertainty of information about the status of stocks relative to B_{MSY}. The standard adopts a number of harvest strategy tiers consistent with the approaches adopted in Australia and by the North Pacific Fisheries Management Council of the United States.

21 The development of a harvest strategy policy (or standard) is not inconsistent with management strategy evaluation; they can represent different elements of an overall fisheries management framework. The layers of a management strategy are depicted below (Source: International Council for the Exploration of the Sea, report of the Study Group on Management Strategies, 2006). The harvest strategy standard outlined in this document operates at the level of a harvest control rule. The New Zealand equivalent of the four inner layers together depicted in the ICES diagram is a fisheries plan.

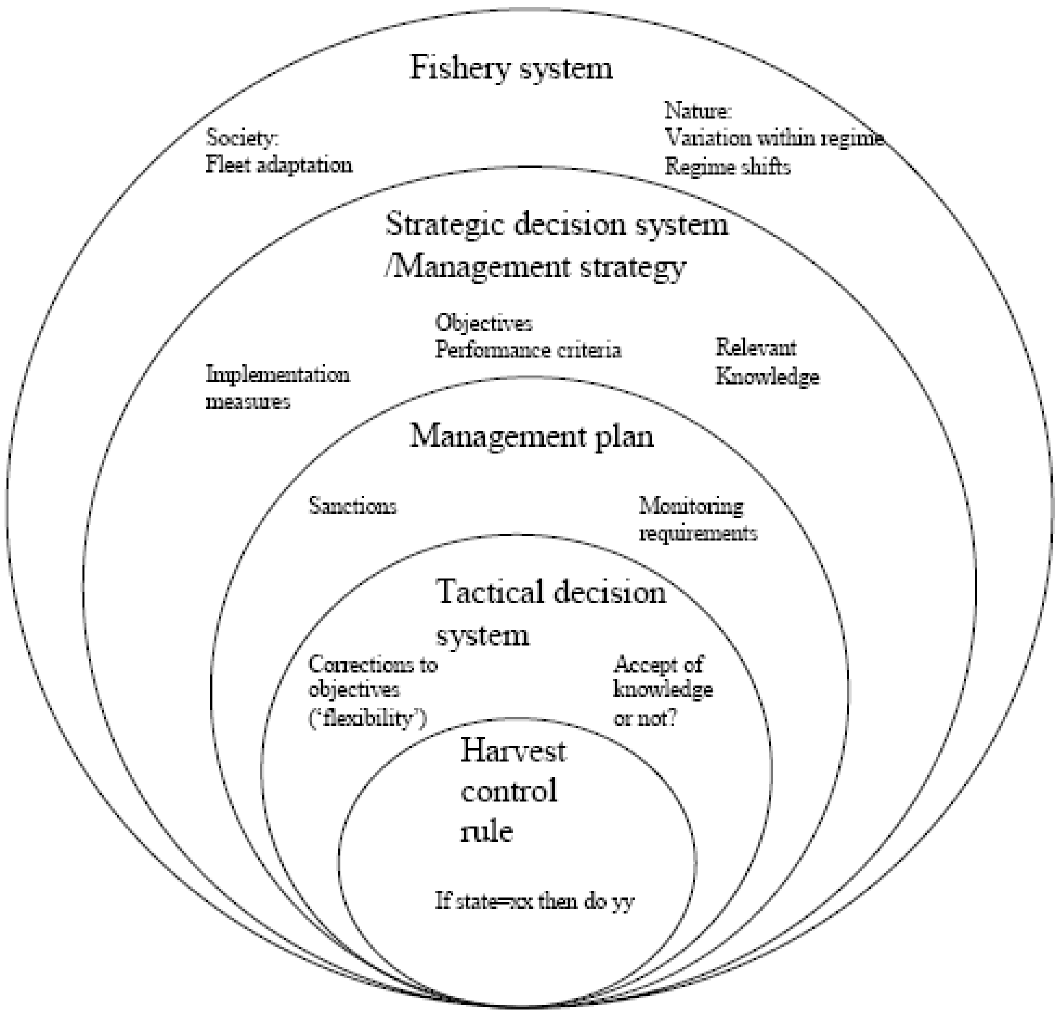

Figure 9: Management Strategy Layers (ICES, 2006)

Appendix II: 1995 United Nations Fish Stocks Agreement, Annex II

Guidelines for the Application of Precautionary Reference Points in Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks.

1. A precautionary reference point is an estimated value derived through an agreed scientific procedure, which corresponds to the state of the resource and of the fishery, and which can be used as a guide for fisheries management.

2. Two types of precautionary reference points should be used: conservation, or limit, reference points and management, or target, reference points. Limit reference points set boundaries which are intended to constrain harvesting within safe biological limits within which the stocks can produce maximum sustainable yield. Target reference points are intended to meet management objectives.

3. Precautionary reference points should be stock-specific to account, inter alia, for the reproductive capacity, the resilience of each stock and the characteristics of fisheries exploiting the stock, as well as other sources of mortality and major sources of uncertainty.

4. Management strategies shall seek to maintain or restore populations of harvested stocks, and where necessary associated or dependent species, at levels consistent with previously agreed precautionary reference points. Such reference points shall be used to trigger pre-agreed conservation and management action. Management strategies shall include measures which can be implemented when precautionary reference points are approached.

5. Fishery management strategies shall ensure that the risk of exceeding limit reference points is very low. If a stock falls below a limit reference point or is at risk of falling below such a reference point, conservation and management action should be initiated to facilitate stock recovery. Fishery management strategies shall ensure that target reference points are not exceeded on average.

6. When information for determining reference points for a fishery is poor or absent, provisional reference points shall be set. Provisional reference points may be established by analogy to similar and better-known stocks. In such situations, the fishery shall be subject to enhanced monitoring so as to enable revision of provisional reference points as improved information becomes available.

7. The fishing mortality rate which generates maximum sustainable yield should be regarded as a minimum standard for limit reference points. For stocks which are not overfished, fishery management strategies shall ensure that fishing mortality does not exceed that which corresponds to maximum sustainable yield, and that the biomass does not fall below a predefined threshold. For overfished stocks, the biomass which would produce maximum sustainable yield can serve as a rebuilding target.

APPENDIX III: RELATIONSHIP BETWEEN FISHING MORTALITY RATES AND EXPLOITATION RATES

Fishing mortality rates (F) are instantaneous rates, akin to the concept of compound interest, but measured on an exponential scale. They are used as a mathematical convenience to deal with the fact that several sources of mortality are acting simultaneously, but not additively. Natural mortality rates (M) are also expressed in instantaneous terms. The sum of fishing mortality and natural mortality is the total instantaneous mortality, Z. Instantaneous rates range from 0 to ∞. A simple formula is required to annualise instantaneous rates. For example, the exploitation rate (E), which is the annualised fishing mortality rate (expressed as either a proportion or a percentage), is obtained by:

$$E = \frac{F}{Z}(1 - e^{-Z})$$

where e is the exponentiation function, and the other symbols are defined above.

The relationship between F and exploitation rate depends on the value of M, as shown in the table below. Zero fishing mortality equates to zero exploitation rate, while infinite fishing mortality equates to 100% exploitation rate. For low F (≤ 0.3) and low M (≤ 0.2) , the exploitation rate expressed as a proportion is similar to the fishing morality rate.

Table 4: Relationship Between Fishing Mortality Rates & Exploitation Rates

			Exploitation rate					Exploitation rate					Exploitation rate	
M	F	Z=F+M	prop	Per-cent	M	F	Z=F+M	prop	Per-cent	M	F	Z=F+M	prop	Per-cent
0.1	0.0	0.1	0.00	0.0	0.2	0.0	0.2	0.00	0.0	0.3	0.0	0.3	0.00	0.0
	0.05	0.15	0.05	4.6		0.05	0.25	0.04	4.4		0.05	0.35	0.04	4.2
	0.1	0.2	0.09	9.1		0.1	0.3	0.09	8.6		0.1	0.4	0.08	8.2
	0.15	0.25	0.13	13.3		0.15	0.35	0.13	12.7		0.15	0.45	0.12	12.1
	0.2	0.3	0.17	17.3		0.2	0.4	0.16	16.5		0.2	0.5	0.16	15.7
	0.25	0.35	0.21	21.1		0.25	0.45	0.20	20.1		0.25	0.55	0.19	19.2
	0.3	0.4	0.25	24.7		0.3	0.5	0.24	23.6		0.3	0.6	0.23	22.6
	0.35	0.45	0.28	28.2		0.35	0.55	0.27	26.9		0.35	0.65	0.26	25.7
	0.4	0.5	0.31	31.5		0.4	0.6	0.30	30.1		0.4	0.7	0.29	28.8
	0.45	0.55	0.35	34.6		0.45	0.65	0.33	33.1		0.45	0.75	0.32	31.7
	0.5	0.6	0.38	37.6		0.5	0.7	0.36	36.0		0.5	0.8	0.34	34.4
	0.6	0.7	0.43	43.1		0.6	0.8	0.41	41.3		0.6	0.9	0.40	39.6
	0.7	0.8	0.48	48.2		0.7	0.9	0.46	46.2		0.7	1	0.44	44.2
	0.8	0.9	0.53	52.7		0.8	1	0.51	50.6		0.8	1.1	0.49	48.5
	0.9	1	0.57	56.9		0.9	1.1	0.55	54.6		0.9	1.2	0.52	52.4
	1	1.1	0.61	60.6		1	1.2	0.58	58.2		1	1.3	0.56	56.0
	1.1	1.2	0.64	64.1		1.1	1.3	0.62	61.6		1.1	1.4	0.59	59.2
	1.2	1.3	0.67	67.2		1.2	1.4	0.65	64.6		1.2	1.5	0.62	62.1
	1.3	1.4	0.70	70.0		1.3	1.5	0.67	67.3		1.3	1.6	0.65	64.8
	1.4	1.5	0.73	72.5		1.4	1.6	0.70	69.8		1.4	1.7	0.67	67.3
	1.5	1.6	0.75	74.8		1.5	1.7	0.72	72.1		1.5	1.8	0.70	69.6
	2	2.1	0.84	83.6		2	2.2	0.81	80.8		2	2.3	0.78	78.2
	2.5	2.6	0.89	89.0		2.5	2.7	0.86	86.4		2.5	2.8	0.84	83.9
	3	3.1	0.92	92.4		3	3.2	0.90	89.9		3	3.3	0.88	87.6
	5	5.1	0.97	97.4		5	5.2	0.96	95.6		5	5.3	0.94	93.9
	10	10.1	0.99	99.0		10	10.2	0.98	98.0		10	10.3	0.97	97.1

APPENDIX IV: YIELD PER RECRUIT AND SPAWNING BIOMASS PER RECRUIT ANALYSES, WITH ASSOCIATED REFERENCE POINTS

Yield per recruit calculations (left diagram, YPR curve, plotted on the right-hand axis) are based on growth (average weights at age), natural mortality at age, and the extent to which fish of a given age are vulnerable to a fishery (e.g. small juvenile fish may not be fully vulnerable to a fishery, either because they mostly occur in different areas, or because they are too small to be retained by fishing gear). As fishing mortality rates (essentially the percentage of a stock removed by fishing in a given fishing year) increase above zero, yield per recruit increases rapidly at first, then reaches a peak and usually begins to decline.

Yield per recruit curves are most commonly expressed in terms of fishing mortality, but the relationship between fishing mortality and exploitation rate is relatively straightforward and the shape of the curves resulting from the two different metrics is basically similar. The fishing mortality rate that corresponds to the maximum yield per recruit is called F_{MAX}. E_{MAX} is simply the equivalent quantity expressed as an exploitation rate (see Appendix III). Neither value can be estimated when the yield per recruit curve is flat-topped, as is often the case. For this reason, and because yield per recruit calculations do not take account of the likelihood that the number of recruits declines with declining spawning biomass, $F_{0.1}$ is often preferred as a biological reference point. $F_{0.1}$ is the fishing mortality rate at which the slope of the yield per recruit curve as a function of fishing mortality is 10% of its value at the origin. $F_{0.1}$ is always lower than F_{MAX}.

Spawning (biomass) per recruit calculations (left diagram, SPR curve, plotted on the left-hand axis; right diagram, plotted by itself in terms of a percentage of the maximum) are based on the same information as yield per recruit calculations, with the addition of a maturity ogive, which expresses the proportion of individuals of a give age that are mature. Spawning biomass per recruit is essentially the *mature* fish that are left over after fishing has taken place. Note that the catch can include immature fish so yield per recruit and spawning biomass pre recruit are not necessarily directly complementary.

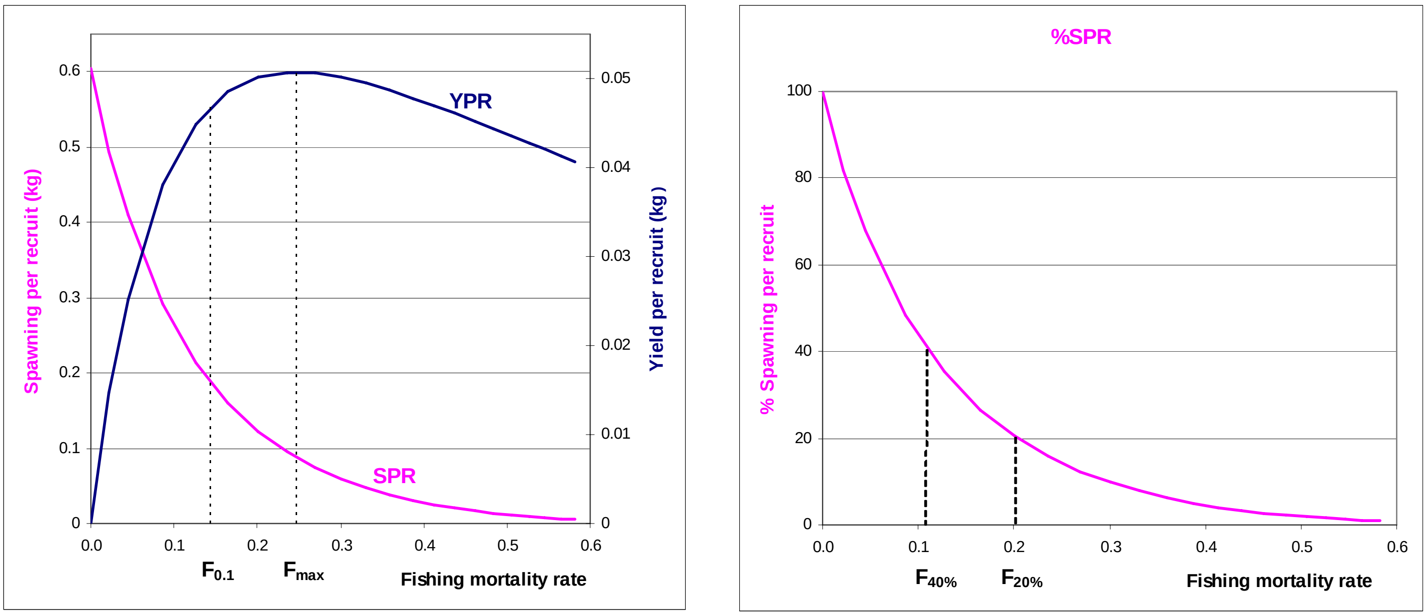

Figure 10: Yield Per Recruit and Spawning Biomass Per Recruit Curves

Spawning biomass per recruit is always at a maximum when there is no fishing. Thereafter, it decreases rapidly as fishing mortality rates increase. It is often plotted as a percentage of its maximum (right diagram) in order to estimate biological reference points that are in a common currency across different species. These reference points are expressed as $F_{\%SPR}$, the exploitation rate corresponding to a specified percentage of the maximum spawning biomass per recruit. For example, the two reference points plotted on the right diagram are the fishing mortality rates corresponding to 40% and 20% of the maximum SPR. SPR reference points of the order of $F_{25\%}$ - $F_{35\%}$ are frequently used as targets for relatively high productivity species, whereas those of the order of $F_{35\%}$ - $F_{50\%}$ may be used as targets for low productivity species.

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