Ministry for Primary Industries
Manatū Ahu Matua

The journey to set targets and limits in fisheries management

- how we got to where we are -

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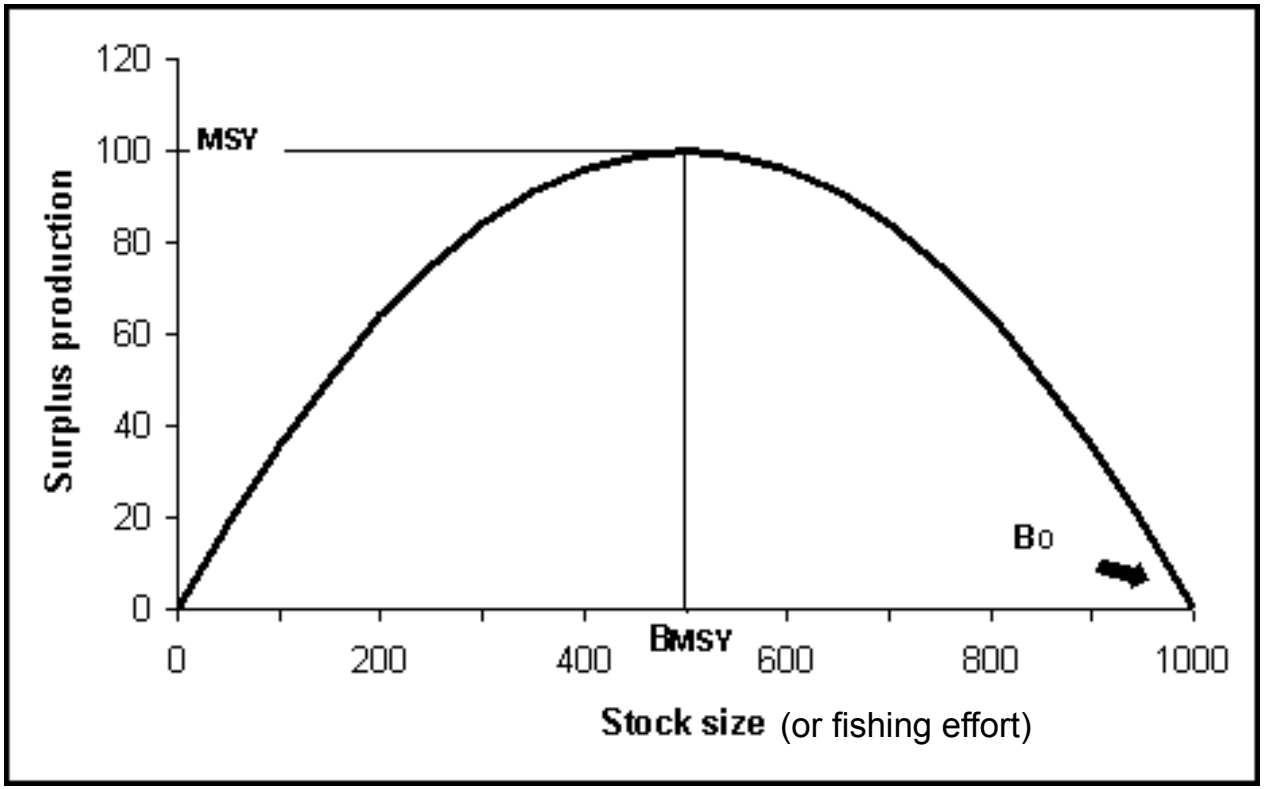
Overview

- The early years:
  - Late 1800s to 1940s
  - 1950s
  - 1960s to 1980s
- Criticisms of MSY & RRPs
- How to make it “work”
- A plethora of target and limit reference points
- Recent developments
- Has it helped?
- Summary and Conclusions

Who invented MSY?



I don't actually know the answer to this question. So if someone can tell me, I'll be eternally grateful.

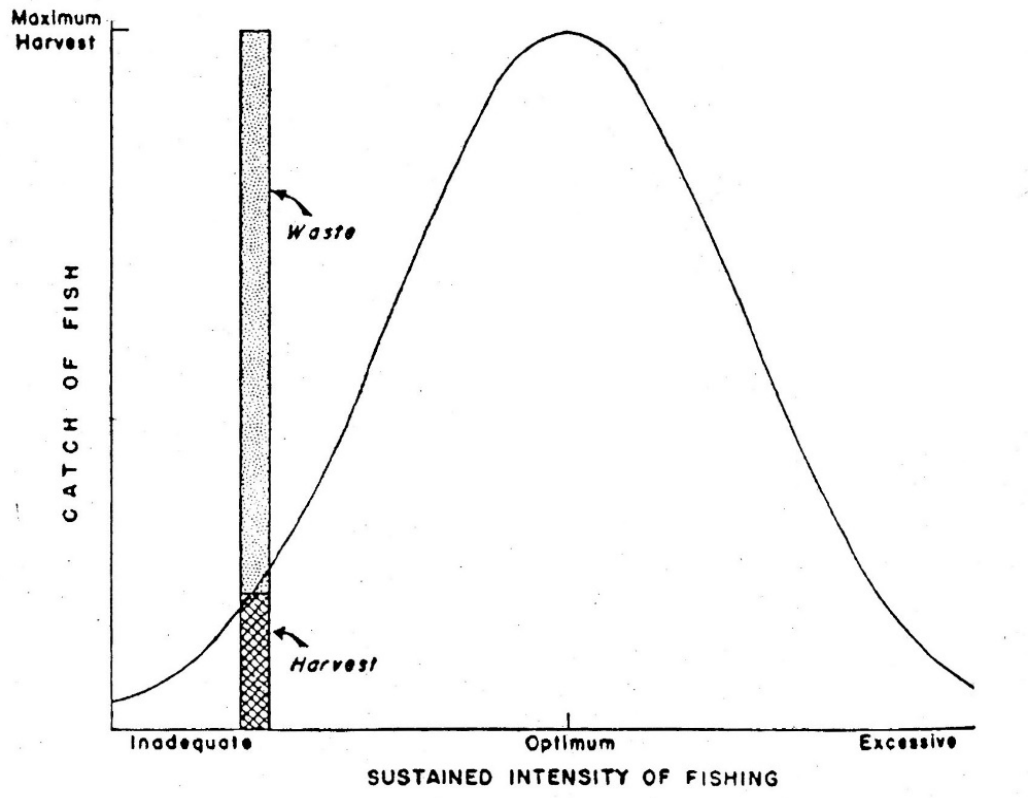
The early years

- Late 1800s: debates about the (in)exhaustibility of fisheries and the need for regulation
  - Thomas Huxley (1883): many of the great sea fisheries are inexhaustible ("but this cannot be said of all", and his statements related to the technology of the time)
  - United States Fish Commission established 12 years earlier to find out why fisheries in New England were collapsing!!
  - Atlantic halibut fishery had already collapsed (has never recovered)
- 1920s to 1940s: Concept of Maximum Sustainable Yield developed
  - F S Russell, M Graham, W F Thompson, J Hjort
  - Surplus production models introduced by Graham (1935)

The Maximum Sustainable Yield curve

Between 1949 and 1955, the U.S. endeavoured to have MSY declared the goal of international fisheries management.

An international MSY treaty was eventually adopted in 1955.

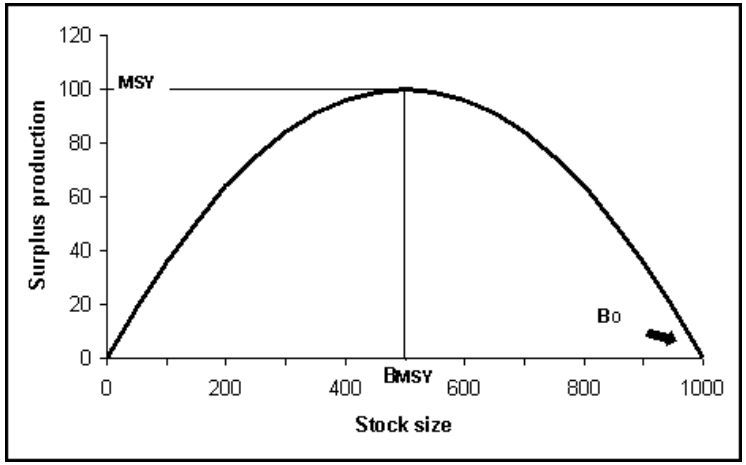


- as published in the *Bulletin of the U.S. State Department* in 1949

1950s: Deterministic equilibrium MSY, MEY and YPR

- Schaefer (1954, 1957): Deterministic, equilibrium, symmetric MSY

In 1968, G. Paulik stated that "…Schaefer's equilibrium yield model is probably the single most important conceptual tool available to anyone concerned with the dynamics of an exploited natural population."



- Gordon (1954): deterministic, equilibrium MEY

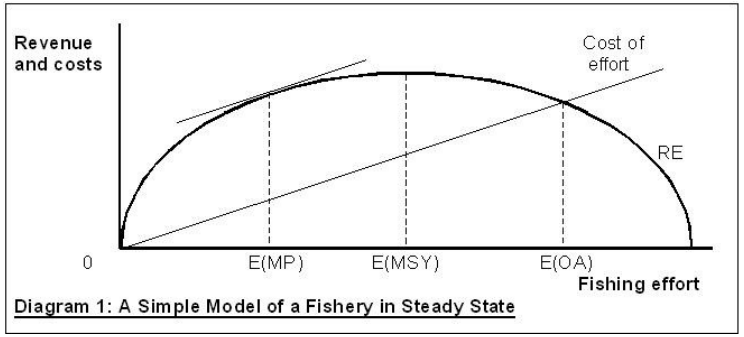
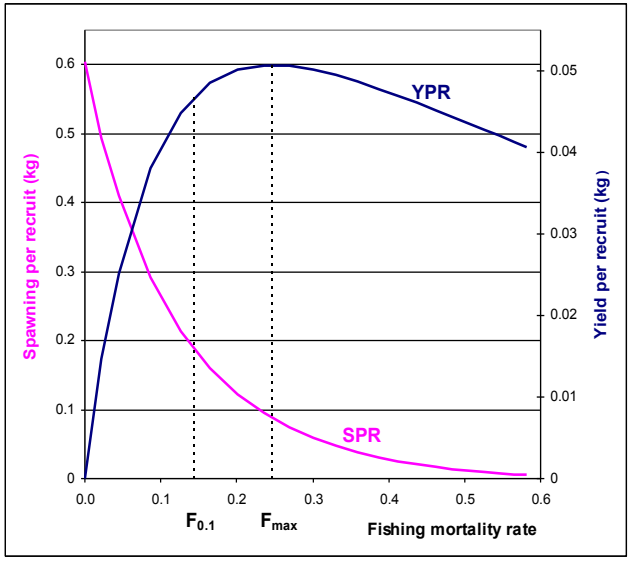


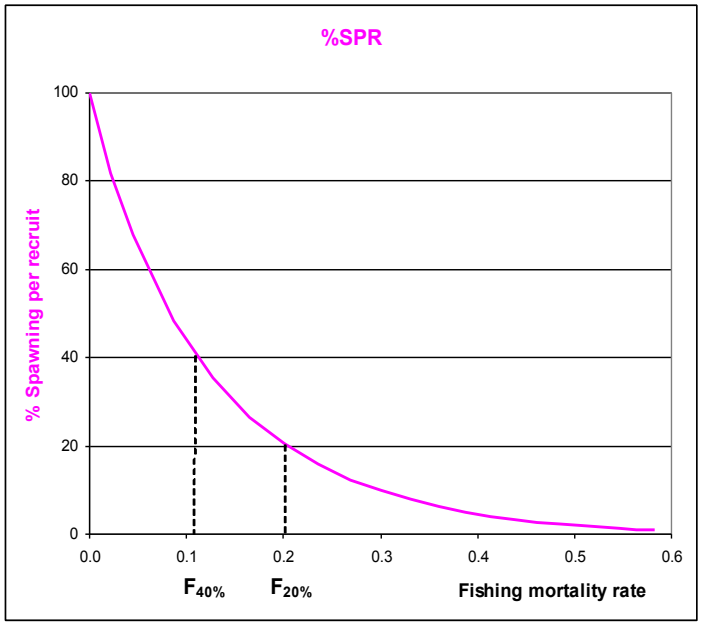
Diagram 1: A Simple Model of a Fishery in Steady State

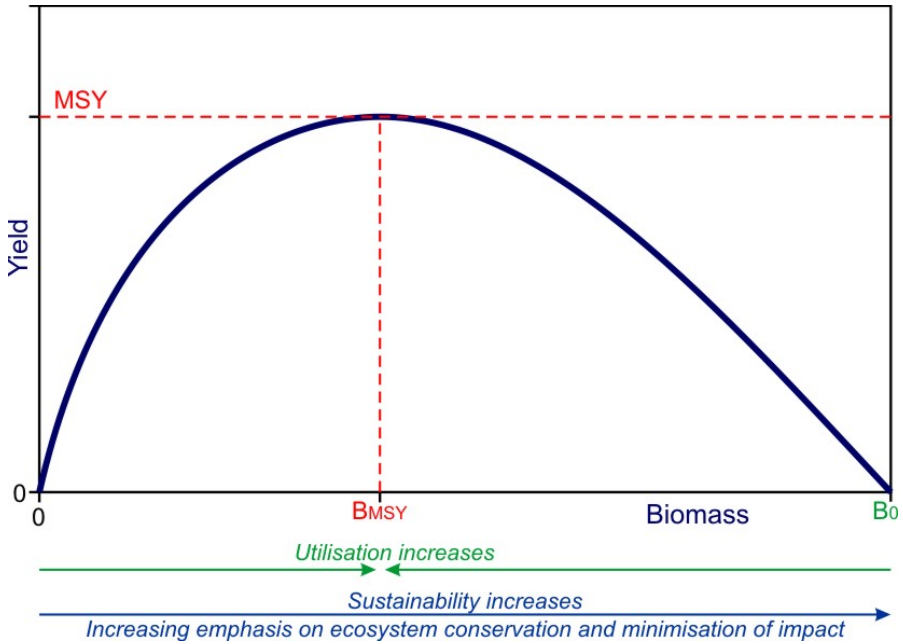
- Beverton and Holt (1957): deterministic, equilibrium YPR (F_{MAX})



1960s-1980s: Adding complexity, realism, using more data

- Pella and Tomlinson (1969), Fox (1970) - Deterministic, equilibrium, asymmetric MSY
- Gulland and Boerema (1973): $F_{0.1}$
- S-R replacement lines
- Increasing use of SSB/R (SPR) reference points
  - $F_{20\%}$, $F_{30\%}$, $F_{40\%}$





Criticisms of MSY & RRPs

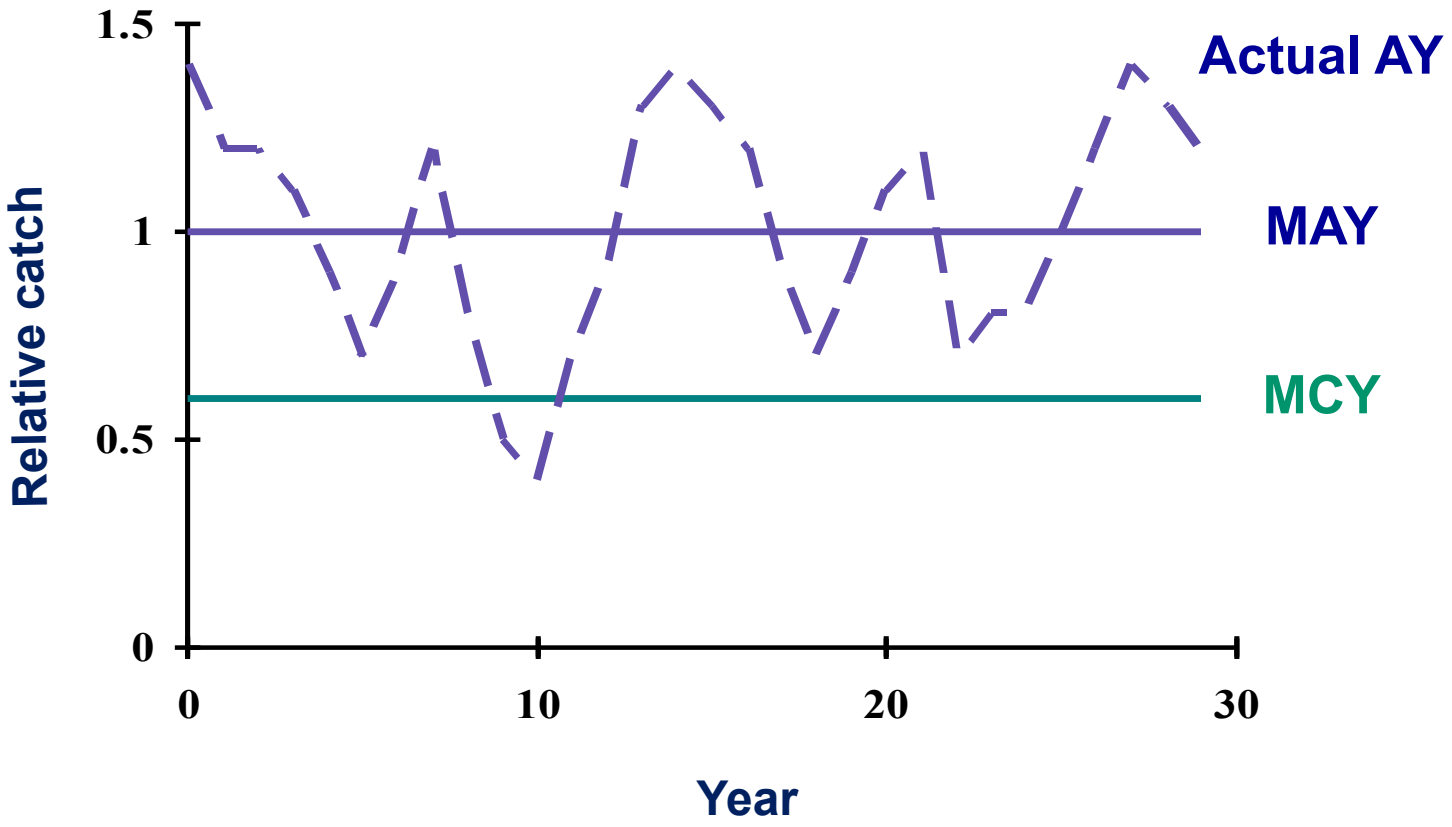
- Larkin 1977, Sissenwine 1978, Punt and Smith (2000), many others
- Larkin (1977): Epitaph to MSY
  - puts populations at too much risk (seeking the absolute MSY with uncertain parameters is risky)
  - doesn't account for spatial variability in productivity
  - doesn't account for bycatch species
  - considers only the benefits not the costs of fishing
- But it was too late: MSY was already embedded in international law
  - e.g. the international MSY treaty of 1955
  - precursors to UNCLOS, which began to be negotiated in 1958
- Its fate (our fate) was solidified in 1982 when it was embedded in UNCLOS and it is now enshrined in dozens if not hundreds of national Fisheries Acts, regional entities such as RFMOs, and other binding and voluntary international instruments, continuing up to this day

So, how have we made it work?

1. Treat it more realistically; transition from MSY as a constant (deterministic, equilibrium) yield to recognition that:
   - The value of MSY & RRPs depends on the model and data used
   - A constant, deterministic MSY is not sustainable in a stochastic environment (Doubleday 1976, Beddington and May 1977, Horwood et al 1979, Kirkwood 1981, many others subsequently); i.e. cannot take deterministic MSY as a constant catch in a variable population (even before considering other real world factors such as model misspecification, assessment errors, parameter uncertainty, etc.)
   - Therefore, the calculation and value assigned to MSY & RRPs depends on the actual harvest strategy employed

- This led to the adoption of two alternative interpretations of MSY in New Zealand's Quota Management System, depending on how frequently TACs are likely to be changed

MSY depends on the actual harvest strategy used



AY = Annual Yield
MAY = Maximum Average Yield, based on constant F or similar
MCY = Maximum Constant Yield

Mace & Sissenwine 1989

So, how have we made it work?

2. Adopt a precautionary approach

a) **Develop limit reference points (LRPs) and risk levels associated with violating them (Annex 2 of the UN Fish Stocks Agreement 1995):**

- Two type of precautionary reference points should be used: conservation, or limit, reference points and management, or target, reference points (para 2)
- Fishery management strategies shall ensure that the risk of exceeding limit reference points is very low ... and target reference points should not be exceeded on average (para 5)

- **This can substantially alter the values of the TRPs**

- Sissenwine (1978) was one of the first to suggest that a more rational interpretation of MSY would be the yield that can be removed in perpetuity from the resource with an accepted low probability of endangering it

- Beddington and Cooke (1983) introduced 20% B_0 as a (somewhat arbitrary) biomass limit and suggested (somewhat arbitrarily) that the probability of falling below it should be no more than 10%
  - This has also been used in New Zealand since about 1992
  - And, it or slight variations of it, have been increasingly adopted in modern times

So, how have we made it work?

3. Incorporate parameter uncertainty
4. Incorporate assessment error
5. Develop proxies and alternatives

6. Focus on a) fishing morality-based reference points that are applied to a variable biomass, rather than a constant MSY, or b) biomass-based reference points that stocks are expected to fluctuate around
   - In ICES and on the east coast of North America and elsewhere, targets have historically been based on fishing mortality
   - On the west coast of North America and in Australia, New Zealand and other countries, there has been a tendency to favour targets based on biomass

Mean $\%B_{MSY}$ / B_0 averaged over other factors

Overall average for entire table = 44.5% B_0

		$\%B_{MSY}/(B_0)$											
		MAYp			MAY5y			MCYp			MCYtb		
	Risk	0	0.2	0.3	0	0.2	0.3	0	0.2	0.3	0	0.2	0.3
Factor	Level												
M	0.05	29	34	42	29	34	42	39	45	51	36	43	50
	0.2	27	37	49	29	39	51	44	54	60	35	51	60
	0.4	28	43	55	32	48	58	45	59	65	38	57	64
Asel	0.5	24	35	47	27	38	49	47	53	58	33	49	58
	1	24	36	48	26	39	50	39	53	59	34	50	58
	1.5	35	42	51	37	44	53	42	52	59	42	52	59
h	0.6	32	39	49	34	41	50	45	55	59	39	52	59
	0.75	29	37	48	31	40	50	45	53	59	36	50	58
	0.95	23	37	48	26	40	51	38	50	58	34	48	57
Sigmar	0	27	30	35	28	31	36	35	38	42	32	37	42
	0.5	28	34	46	30	38	48	44	52	58	37	49	57
	1	29	49	65	32	53	67	48	67	75	40	65	75
Rho	0	28	35	44	30	37	46	42	49	55	36	46	54
	0.6	28	41	53	30	43	54	43	56	63	37	54	62
Aerr	F	27	37	47	29	39	49	38	48	54	33	46	54
	T	28	39	50	31	42	52	47	58	63	39	54	63

So, how have we made it work?

7. **Other approaches that have been tried:**

- Treat F_{MSY} as a limit, not a target
  - **Annex 2 of the UN Fish Stocks Agreement (1995)**
    - **The fishing mortality rate which generates maximum sustainable yield shall be regarded as a minimum standard for limit reference points (para 7)**
      - **But this is based on deterministic thinking!**
- Develop (potentially-conservative) proxies for F_{MSY}, and for (other) potential limit reference points
- Focus more on avoiding limit reference points rather than achieving target reference points (which often results in a change to the effective target level)

Resulted in a plethora of reference points

(particularly in ICES)

Fishing mortality-based BRPs:

- F_{MSY}, F_{max}, $F_{0.1}$, $F=M$, F_{rep}, F_{med}, F_{high}, F_{low},
- F_{ext}, F_{crash}, F_{loss}, $F_{20\%}$, $F_{30\%}$, $F_{35\%}$, $F_{40\%}$,
- F_{lim}, F_{PA}, F_{buf}, F_{OPH}

Biomass-based BRPs:

- B_{MSY}, 30-60% B_0, MBAL, B_{lim}, B_{PA}, B_{buf}, historical reference period (B or CPUE)

Others:

- Yield-based BRPs; e.g. MSY
- Recruitment-based BRPs

Johannesburg Declaration (2002)

- **Article 31(a) of the Implementation Plan adopted at the World Summit on Sustainable Development (WSSD), 4 September 2002, refers to maintaining or restoring "*stocks to levels that can produce the maximum sustainable yield with the aim of achieving these goals for depleted stocks on an urgent basis and where possible not later than 2015*"**
  - **This and other considerations have caused ICES and other entities to once again bring the focus back to MSY & RRPs, particularly B_{MSY}, and many of the former *F*-based targets have fallen into disuse, or are only used for a few stocks**

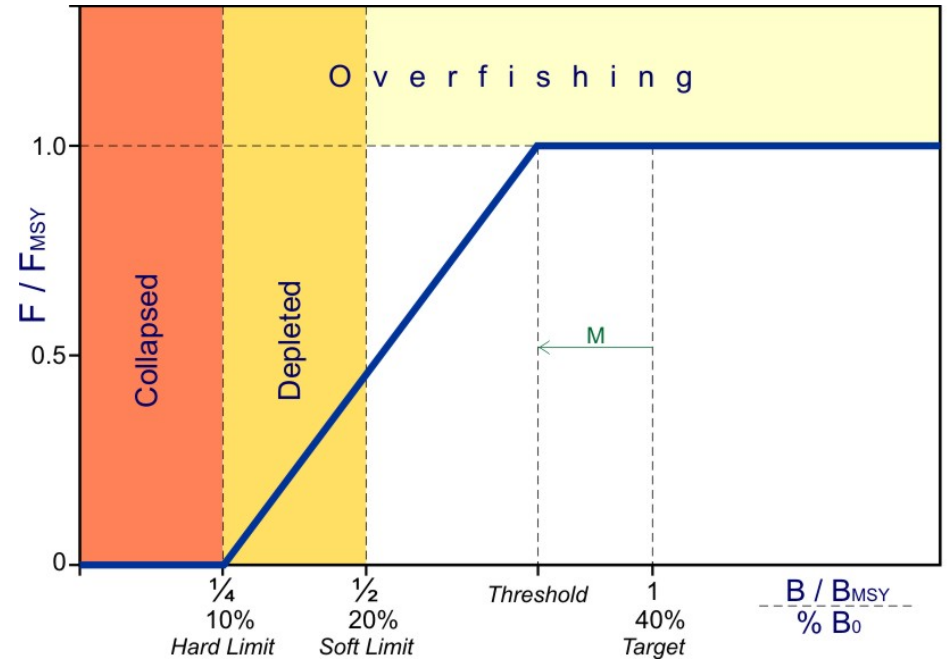
Recent developments

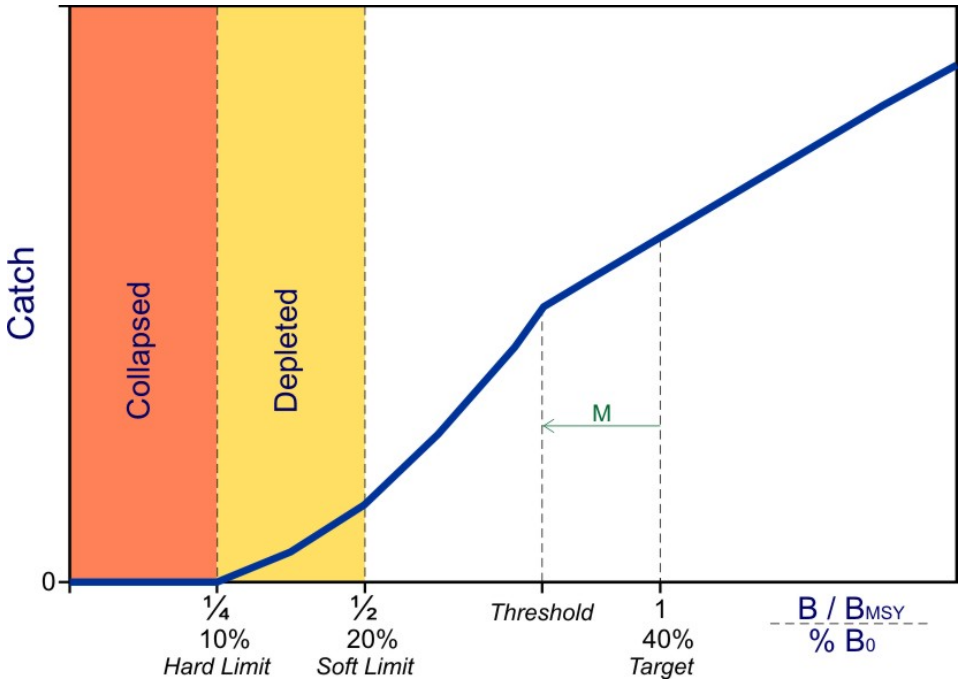
- Harvest Control Rules
  - Harvest Strategy Standards or Policies (New Zealand / Australia, other)
- Management Strategy Evaluation / Management Procedures
- Multispecies / ecosystem reference points
  - None of which are mainstream yet
- Data poor reference points
- Further development and incorporation of economic reference points
  - Australia is the only country that has comprehensively embraced MEY, *per se*, to date, although economic objectives certainly form a part of management decisions in many instances
- Incorporation of social objectives (into reference points, not just fisheries management objectives = one of the aims of the MYFISH project)

Harvest Control Rules

Over the last two decades, target and limit reference points have been incorporated into harvest control rules that may include some or all of a biomass target, a biomass limit, a fishing mortality target and a fishing mortality limit, as well as management actions depending on the stock status relative to the reference points.

I believe that, for most stocks, targets should primarily be based on fishing mortality and limits should be based on biomass.





The Dark Side of Reference Points

Hilborn (2002)

- (1) uncertainties in current stock biomass and virgin stock biomass
- (2) inappropriateness of reference points applied to species for which they were not derived
- (3) reference-point use produces an environment in which stock-assessment scientists rarely evaluate alternative management policies
- (4) reference points as a displacement activity for scientists that keeps them from working on more significant problems in fisheries management

On the contrary

- I maintain that defining and implementing targets and limits for our world's wild fisheries has been instrumental in ending overfishing and rebuilding depleted fish stocks
  - particularly in the last two decades (i.e. starting about the mid-1990s)

- This has been achieved due to:
  - considerable improvements in fisheries science and modelling
  - a more solid foundation for fisheries management measures
  - increased involvement of stakeholders and the public in fisheries management decisions
  - increased awareness of issues
  - stronger legislation, policies, and binding and voluntary international agreements with time-bound deadlines for implementation

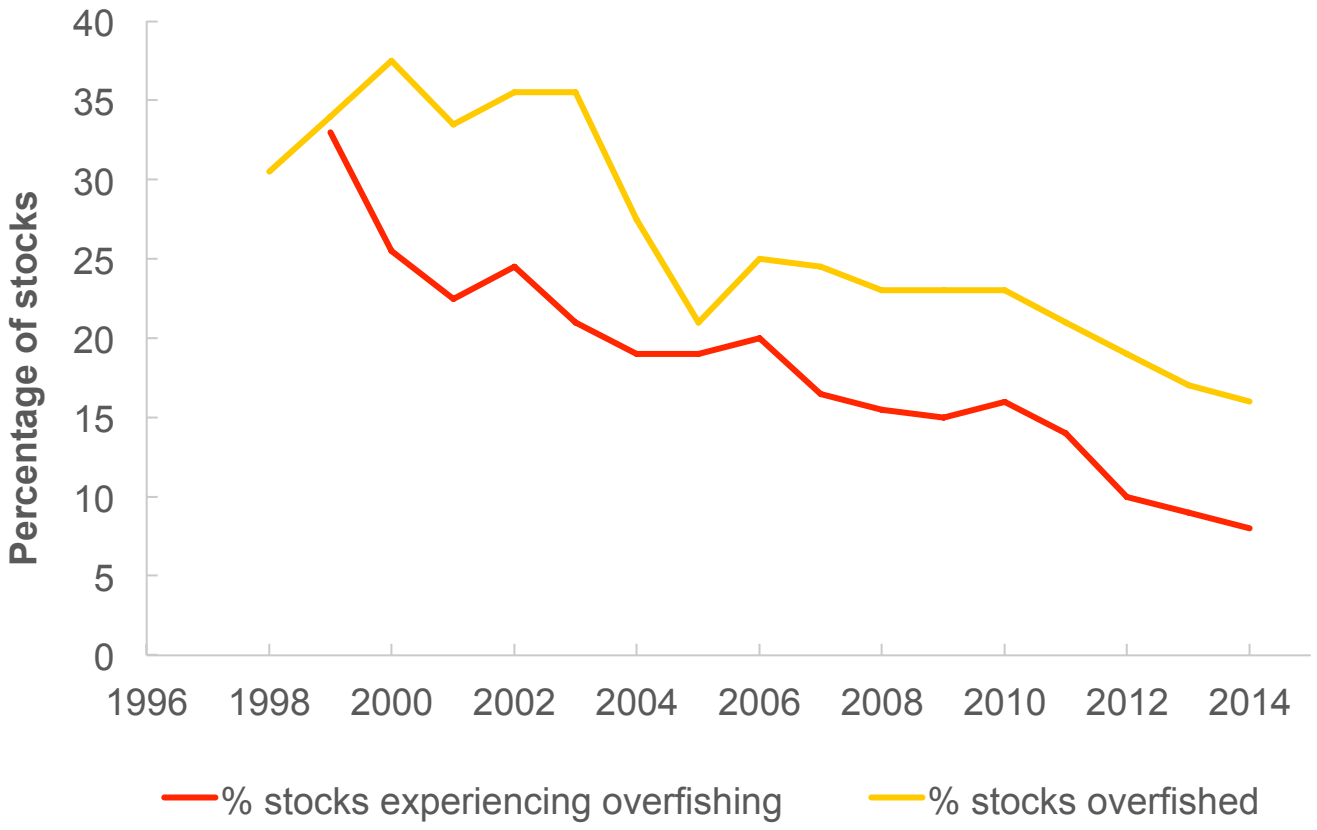
Status of world's major (target) fisheries

FAO 2010 report (2008 data)	
Under-exploited	3%
Moderately-exploited	12%
Fully-exploited	53%
Over-exploited	28%
Depleted	3%
Recovering from depletion	1%

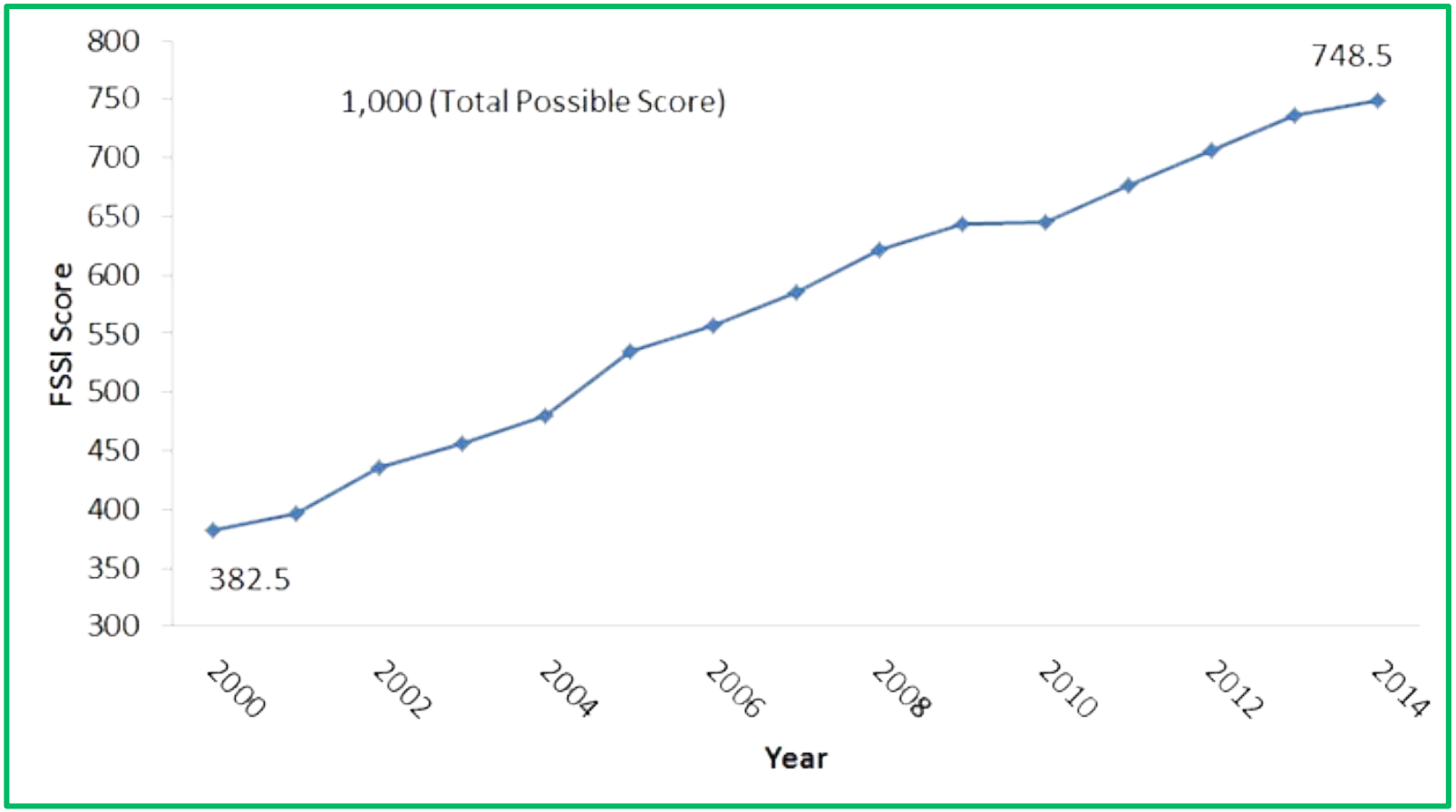
FAO 2012 report (2009 data)	
Under-exploited	12.7%
Fully-exploited	57.4%
Over-exploited	29.9%

FAO 2014 report (2011 data)	
Under-fished	9.9%
Fully-fished	61.3%
Overfished	28.8%

Status of U.S. fish stocks 1998-2014



US Fish Stocks Sustainability Index (FSSI)



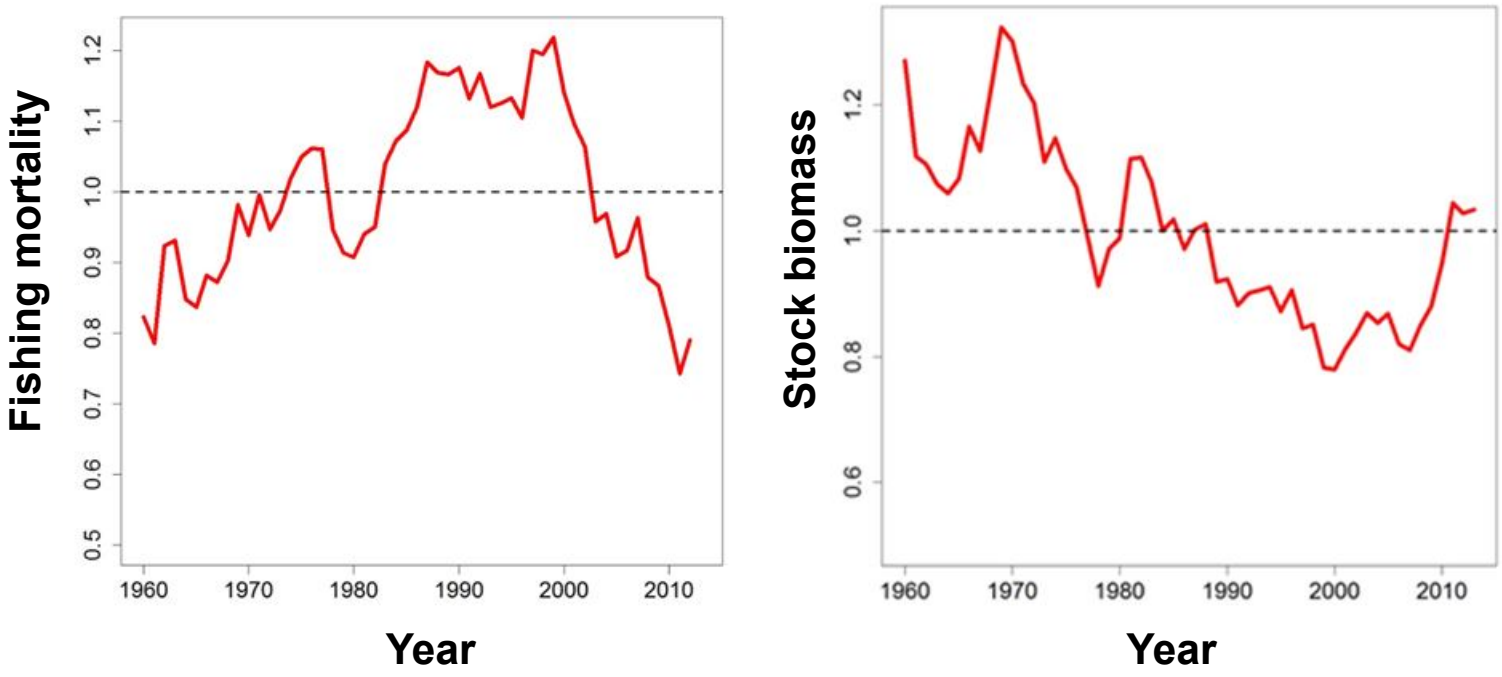
Points awarded for:

- Overfished status is known; overfishing status is known
- Not overfishing
- Not overfished
- Above 80% B_{MSY}

Improvement in the status of ICES stocks

- **Fishing has generally progressed towards MSY (fishing at or below MSY) in all areas of the Northeast Atlantic, North Sea and Baltic Sea since 2006. Between 2006 and 2014:**
  - **the number of stocks fished at MSY increased from 2 to 26**
  - **the number of stocks inside safe biological limits has risen from 11 to 21**
  - **the number of stocks with quantitative catch advice rose from 59 to 72**

Combined results for 85 major fish stocks:



Status of New Zealand fish stocks of known status

STOCK AND FISHERY STATUS INFORMATION BY NUMBERS, VALUE AND VOLUME: 2008-15

OVERFISHED | HARD LIMIT | OVERFISHING | MANAGEMENT TARGET

Inconsistent treatment of MSY and RRPs nowadays

- Deterministic or simple stochastic average?
- Incorporation of other factors to take it closer to the "real world"?
- Is (e.g.) 40% B_0 a B_{MSY} proxy (as is often reported in the US and elsewhere), or a target that is higher than (deterministic) B_{MSY} (as reported by some RFMOs)
  - B_{MSY} proxies of ~40% B_0 have been used for some time in the US and elsewhere (e.g. New Zealand and Australia), with "overfished" defined as being below half that level
  - Until recently, RFMOs tended to set deterministic B_{MSY} as the target and defined "overfished" as any biomass below that; more recently some (e.g. WCPFC) have been exploring the use of 40-60% B_0 as targets and using 20% B_0 as a limit
- This creates complexities for incorporating economic and social objectives into reference points themselves (which MYFISH is trying to do), rather than just considering these factors in overall management objectives

Summary and Conclusions

- MSY & RRPs have been the key TRPs almost throughout the history of fisheries management
- Thinking has evolved from deterministic, equilibrium concept through incorporation of greater realism; now often modified by LRPs
- Interesting evolution from MSY *itself*, to F_{MSY} and other *F*-based reference points, to B_{MSY} and other *B*-based reference points
- Also an interesting evolution of default estimates of B_{MSY} from 50% B_0, to ~15-30% B_0, to 40-60% B_0
- LRPs may be more powerful than TRPs – if fisheries managers are required to ensure a high probability they are not violated
- Both targets and limits are essential for multispecies, ecosystem, economic and social considerations
- **One challenge is to develop RPs that incorporate these factors, while still retaining simplicity, logic, ease of understanding to the public, and operational flexibility**

Thank you for
your attention