Limit Reference Points in fisheries management and their application for tuna and billfish stocks

SAC-08-05e(ii)

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Outline

- Reference Points (RP)
  - Biomass, Mortality, Empirical
  - Target, Threshold, Limit, Rebuilding target
- Harvest Control Rules (HCR)
- Limit Reference Points, considerations
- RP and HCR for tuna and billfish stocks
- Summary

Reference Points

- Guidelines for management. Benchmarks against which the abundance of the stock, the fishing mortality rate or economic and social indicators can be measured to determine its status.

Reference Points

- May be based on exploitation rates, biomass or empirical data
- F_{MSY} and B_{MSY} dependent on **stock-recruit relationships**
- B_{MEY} based on **economics**
- F_{max}, $F_{0.1}$, $F_{35\%}$, $F_{40\%}$ based on **per-recruit** (assumes recruits independent of stock size)

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Some example Reference Points Alphabet soup?

Reference point	Description	
%SPR	spawner per recruit as a percentage of the unfished spawner per recruit - usually set in terms of the harvest rate that implies this	Per recruit
B/B_0	biomass relative to unexploited biomass (or often defined in terms of spawning biomass).	Ad hoc
B_{msy}	the biomass which corresponds with maximum sustainable yield	MSY
MBAL	(Minimum Biological Acceptable Level) a spawning biomass level below which, observed spawning biomasses over a period of years, are considered unsatisfactory and the associated recruitments are smaller than the mean or median recruitment.	Historic estimates of S & R
F_{max}	Fishing mortality rate which corresponds to the maximum yield per recruit (as a function of fishing mortality)	Per recruit
$F_{0.1}$	fishing mortality rate at which the slope of the yield per recruit curve (as a function of fishing mortality) is 10% of its value near the origin. (Similarly defined $F_{0.2}$ has been used in some cases; see Caddy, 1998)	Per recruit
$F_{spr.x\%}$	fishing mortality rate which corresponds to spawner per recruit being x% of unfished spawner per recruit (values of 30%, 35%, 40% have been used; see e.g. Mace and Sissenwine, 1993)	Per recruit
F_{low}	fishing mortality rate on an equilibrium population with a SSB/R equal to the inverse of the 10^{th} percentile of the observed R/SSB	Historic estimates of S & R
F_{med} (F_{rep})	fishing mortality rate on an equilibrium population with a SSB/R equal to the inverse of the median (50^{th} percentile) of the observed R/SSB	Historic estimates of S & R
F_{high}	fishing mortality rate on an equilibrium population with a SSB/R equal to the inverse of the 90^{th} percentile of the observed R/SSB	Historic estimates of S & R
F_{msy}	fishing mortality rate which corresponds to the maximum sustainable yield as estimated by a production model (or age-based model with stock-recruit curve)	MSY

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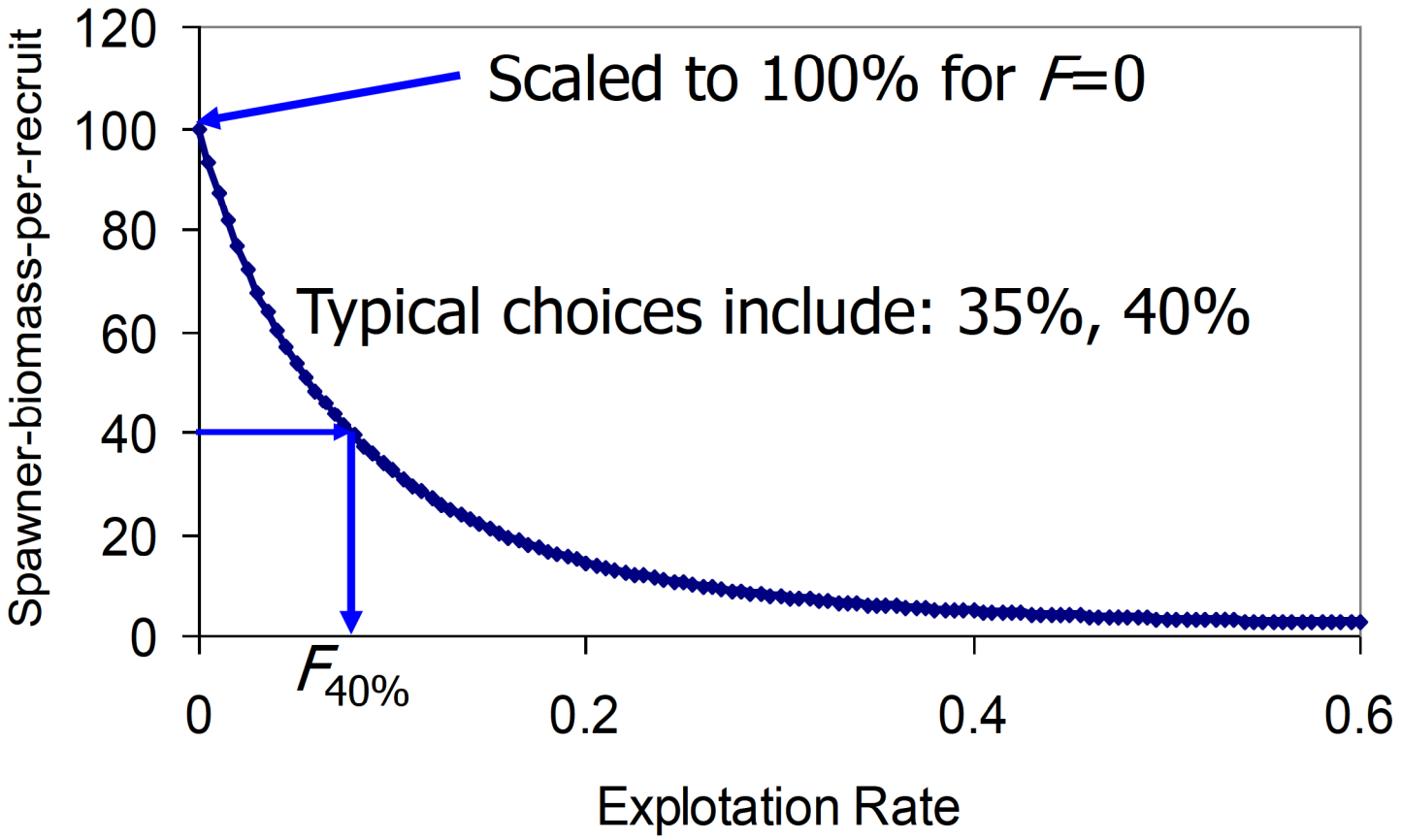
From Davis and Basson, 2012

Spawner Biomass-per-Recruit Reference Points

- **SPR** rates refer to the fishing mortality rate that corresponds to levels that would reduce the *unfished* **S**pawner biomass **P**er **R**ecruit to a certain percentage
  - e.g, if you have 100 recruits, how many survive to spawn, how much they weigh or how many eggs they produce?
  - Depends on: gear selectivity, growth, fecundity at age, natural mortality rate

Spawner Biomass-per-Recruit Reference Points



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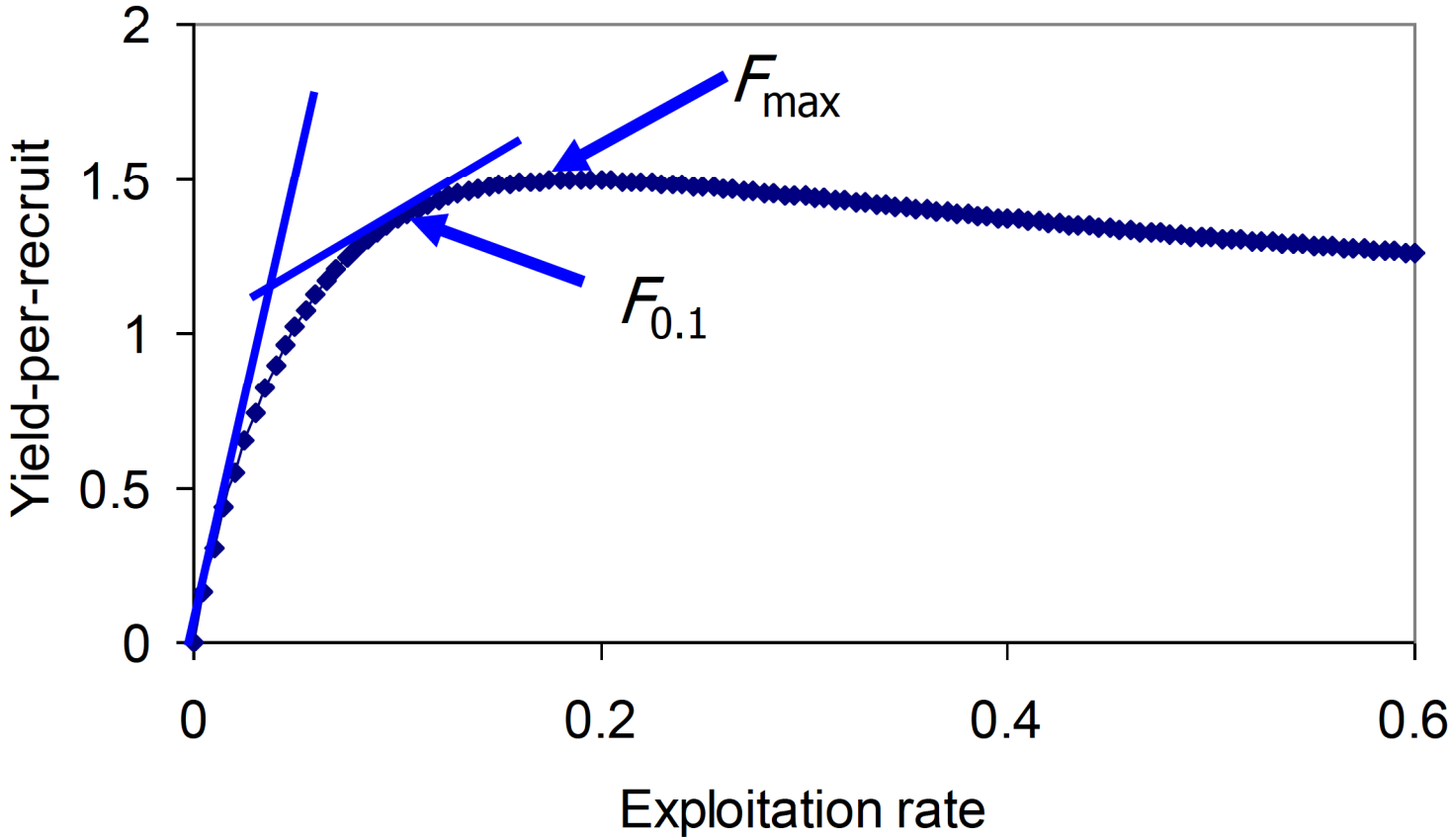
Yield-Per-Recruit Reference Points



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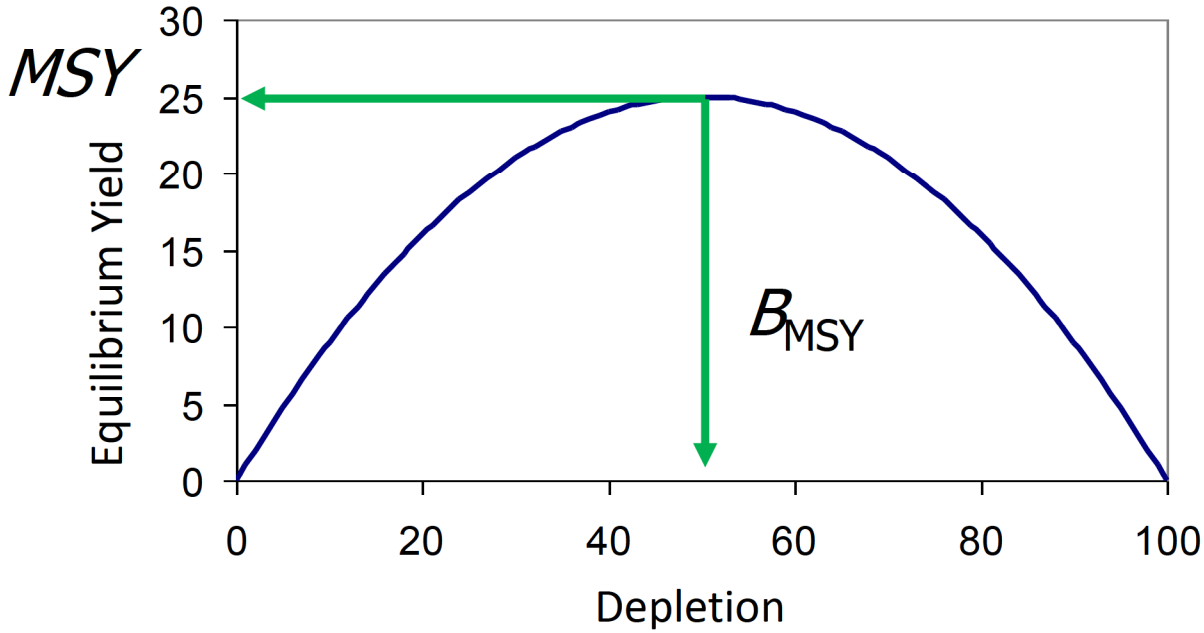
MSY Reference Points

- B_{MSY}: biomass at which Maximum Sustainable Yield *MSY* is achieved.
- Shape depends on model: e.g. Schaefer



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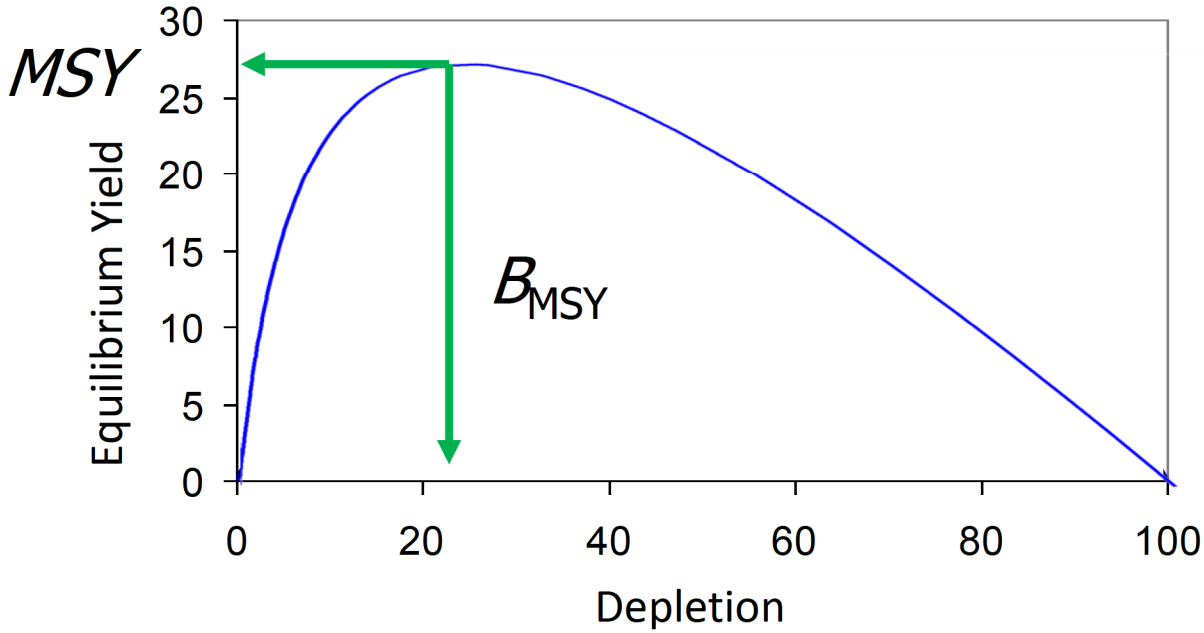
MSY Reference Points

- B_{MSY}: biomass at which Maximum Sustainable Yield *MSY* is achieved.
- Shape depends on model: e.g. (Statistical integrated age-structured model)



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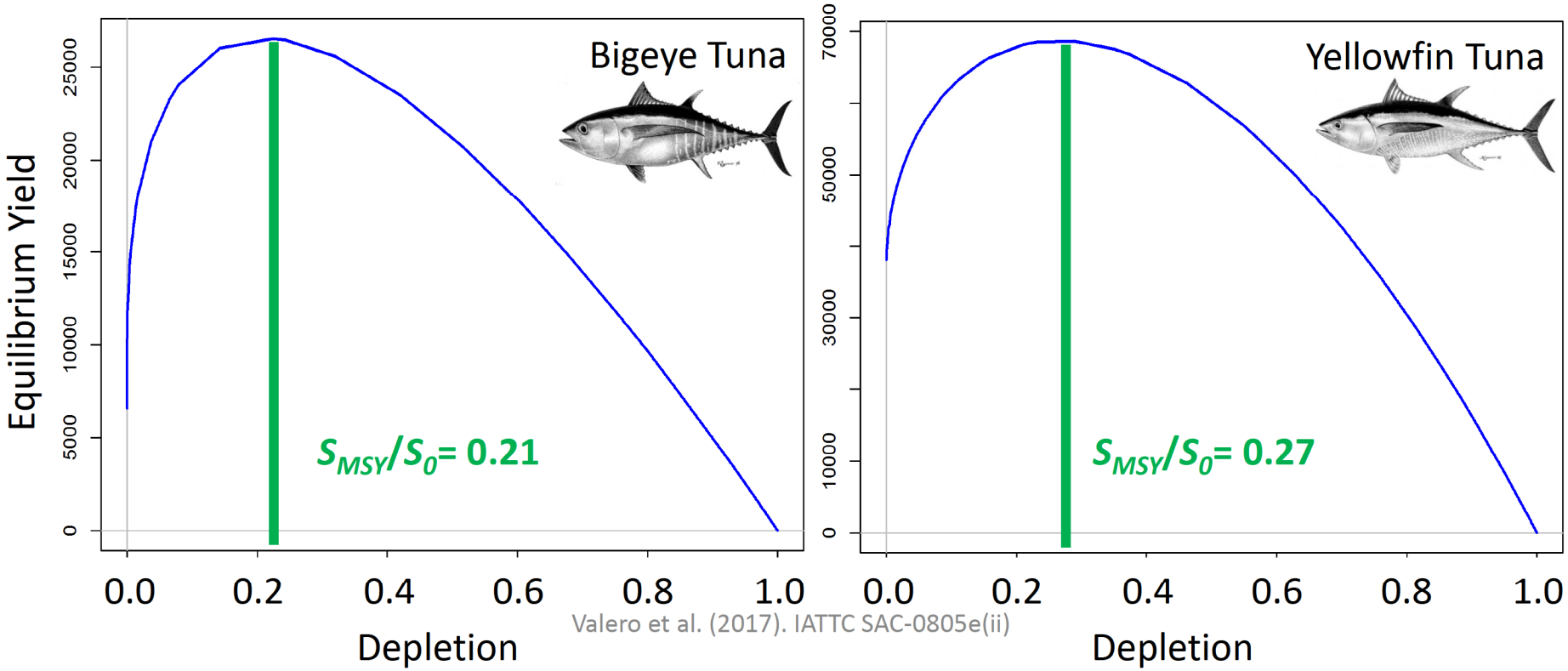
Other Biomass Reference Levels

- 20%B_0 – e.g. consider no policy with greater than 10% probability of dropping below 20% B_0 over a 20-year projection period.
- 20%B_0 commonly used LRP based on work by Beddington and Cooke (1983); Francis (1992) and Myers *et al*. (1994).
- However, 20%B_0 produces very close to MSY for most fish stocks. Thorson *et al*. (2011) found that B_{MSY} ranged from 26–46%B_0 for a range of 147 stocks
- Problems with approaches based on a fixed proportion of B_0: arbitrary, too cautious for some species, not cautious enough for other species.

MSY Reference Points

- B_{MSY}: biomass at which Maximum Sustainable Yield *MSY* is achieved.
- Shape depends on model and biology (M, h, growth) and selectivity



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MSY Reference Points

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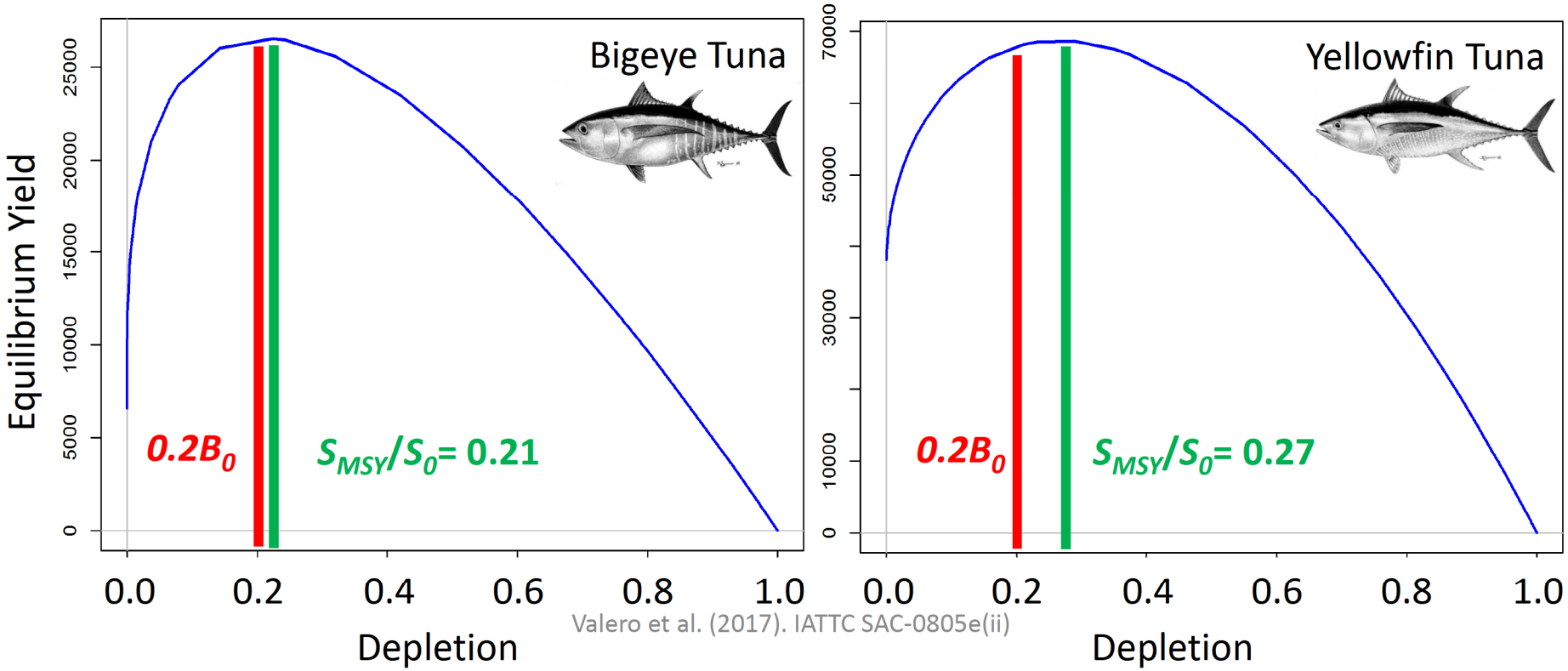

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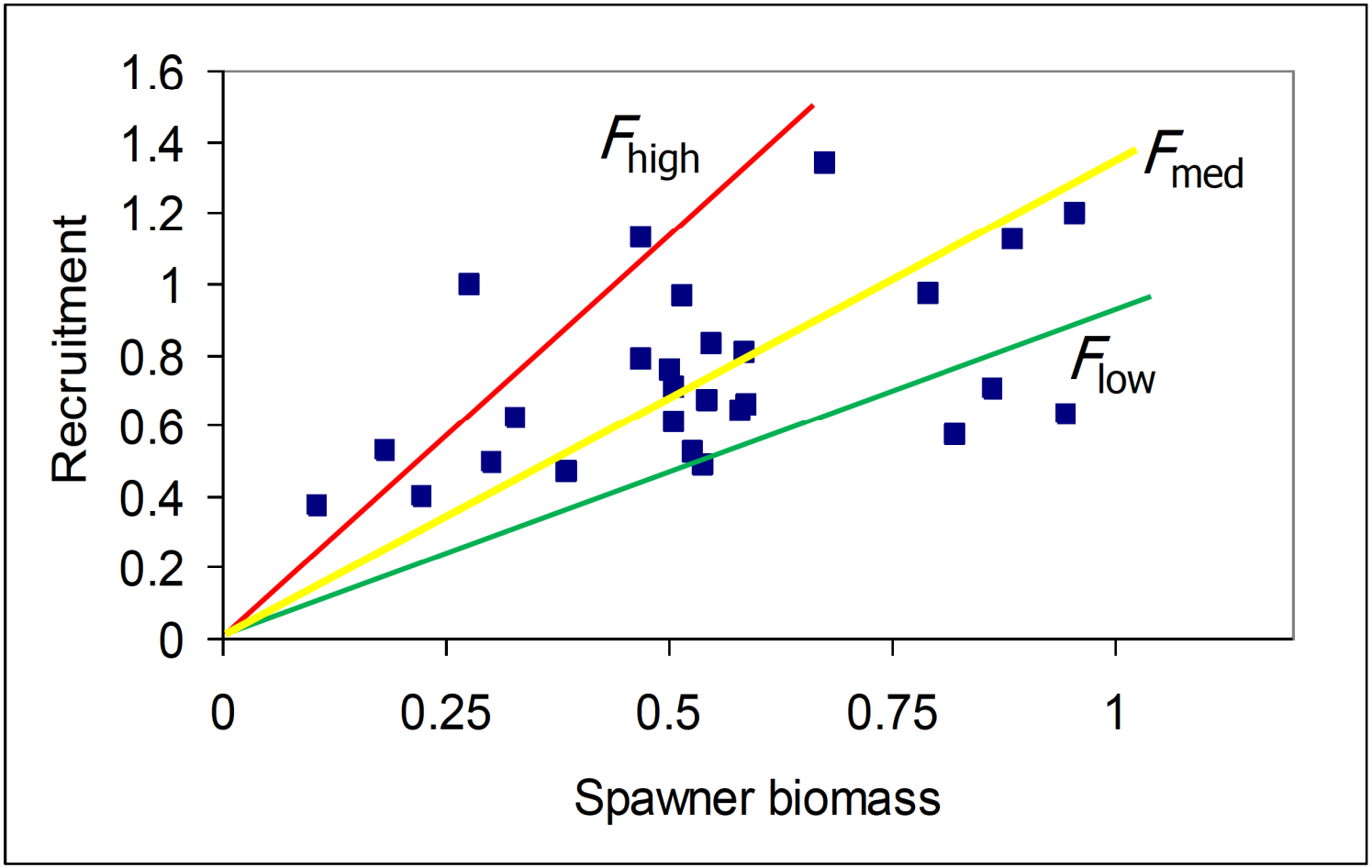
Stock-Recruitment Relationship Reference Points



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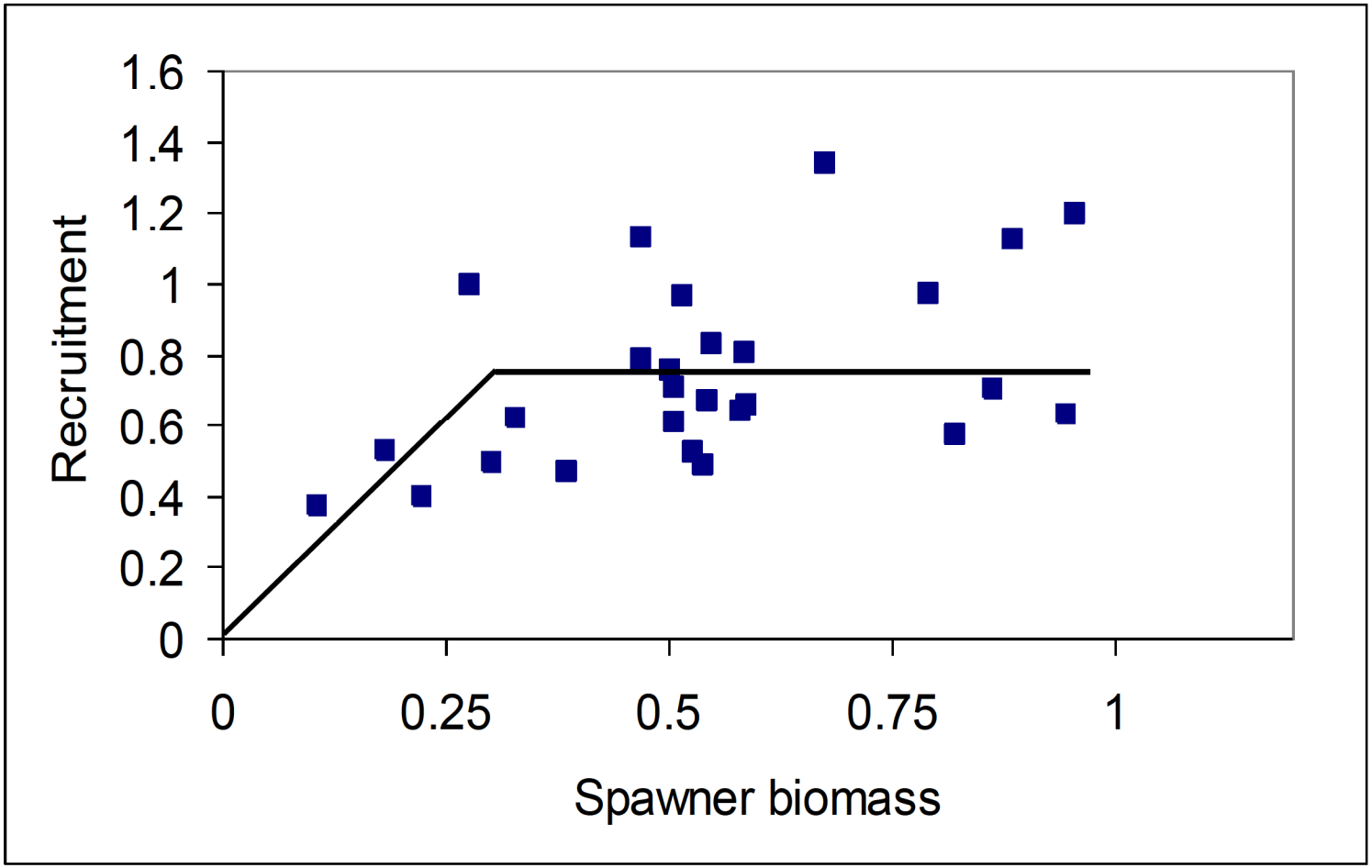

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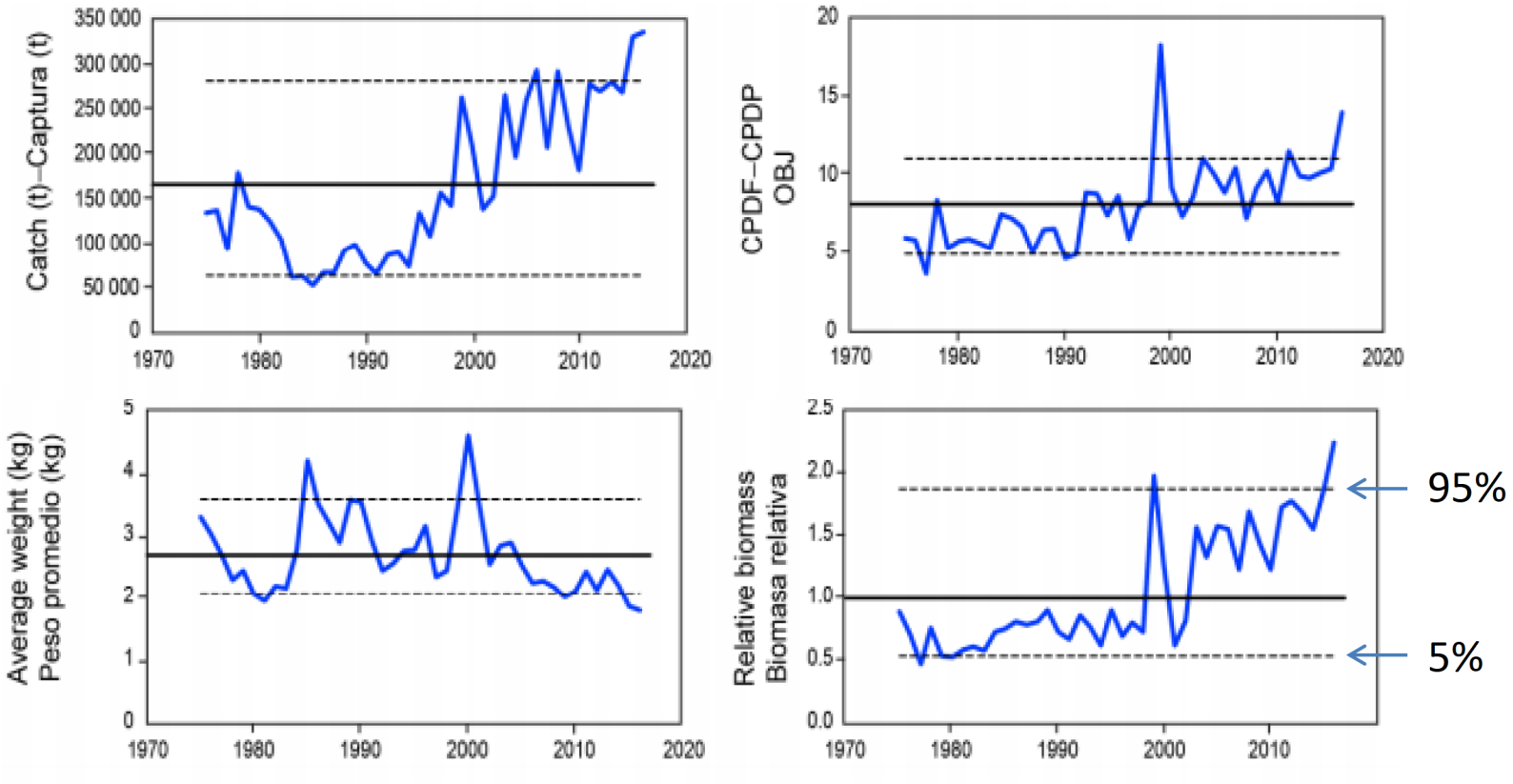
Empirical Reference Points

Skipjack tuna (Maunder 2017)



- PROS: Easier to compute, understand and communicate.
- CONS: Not commonly used, potential confounding of fishery and population processes, not clear if they are robust.

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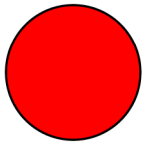
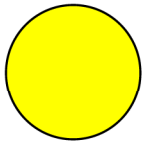
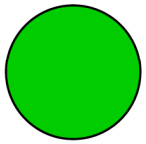
Reference Points



Limit Reference Point



Threshold Reference Point



Target Reference Point

Target Reference Points

- Should be achieved on average according to a given set of management objectives. It corresponds to a state of a fishery and/or a resource which is considered desirable.

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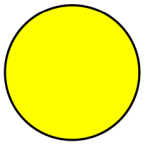
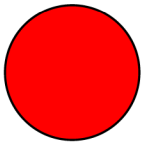
Threshold Reference Points



Indicates that biomass has fallen below the Target, or fishing mortality has increased above its target, to the extent that additional management action may be required in order to prevent the stock from declining further and possibly breaching the limit, also to move it back to target

Limit Reference Points



Should not be exceeded with any substantial probability according to a given set of management objectives. Beyond this limit the state of a fishery is not considered desirable and remedial management action is required. When a stock is at very low abundance, they are often taken as interim rebuilding targets and/or trigger fishery closures.

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Rebuilding Targets

Implemented for depleted stocks. Important to consider rebuilding level, probability and timeline of recovery, subsequent actions after recovery such as defining a target reference point and rebuilding to it

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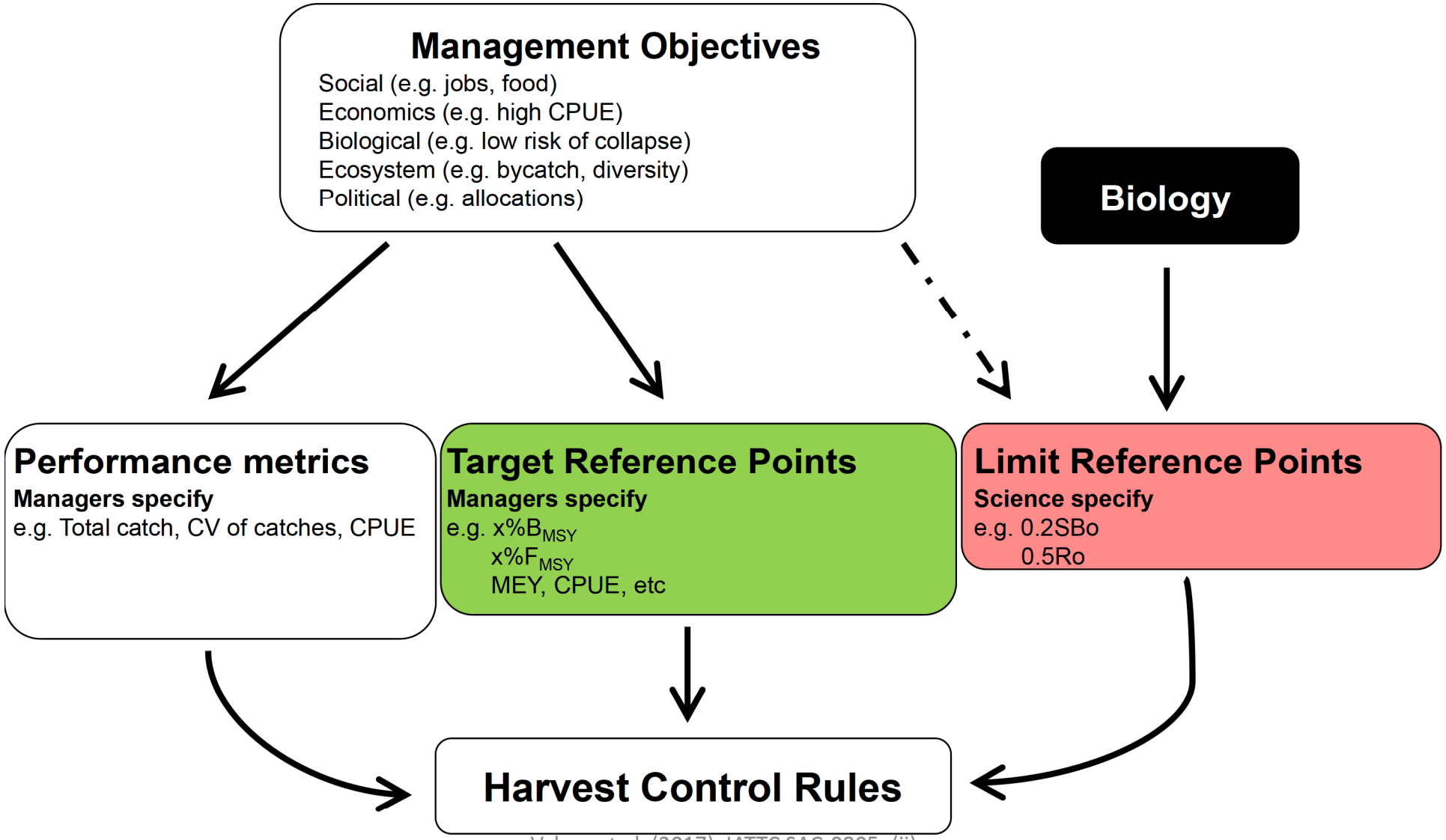
Management objectives, Reference Points and Harvest Control Rules.



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Modified from Berger et al. 2012

Harvest Control Rules

- Rules that specify **pre-agreed** management actions in response to changes in the stock and/or environmental, economic factors relative to pre-established **reference points**, **or trends** in stock indicators.

Harvest Control Rules

- Operationalize **management objectives**
- Integrate management elements (**reference points**)
- Specify **pre-agreed management responses** to changes in the status of the stock
- Increase **transparency** in how harvest management decisions are made
- Provide a means for rational fisheries management strategies through **science-based decision-making.**

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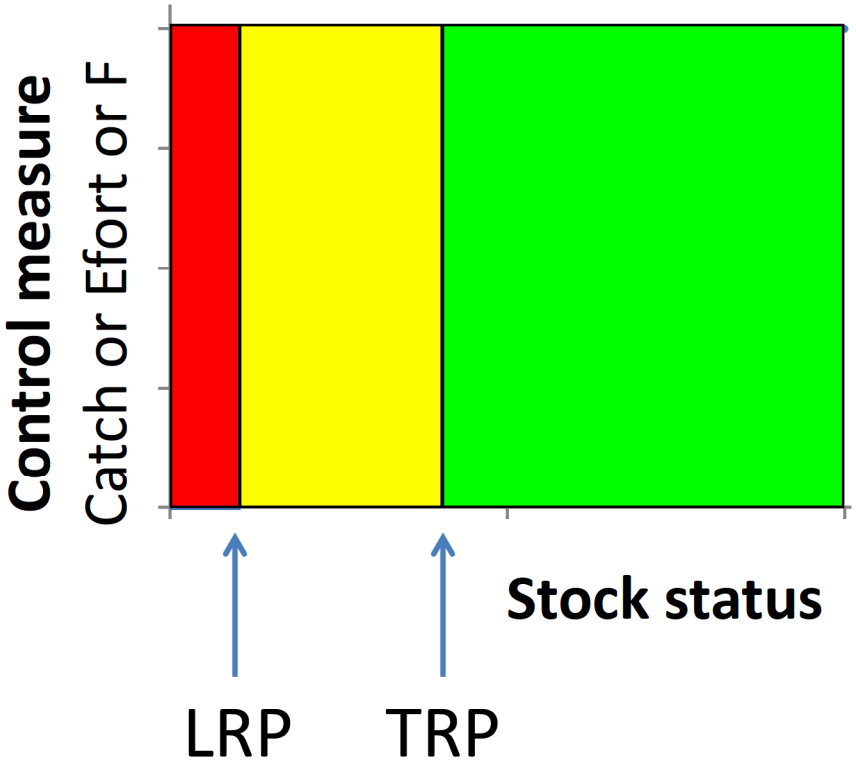
Harvest Control Rule elements



- LRP cannot be evaluated in isolation of other elements of strategy (TRP, HCR)

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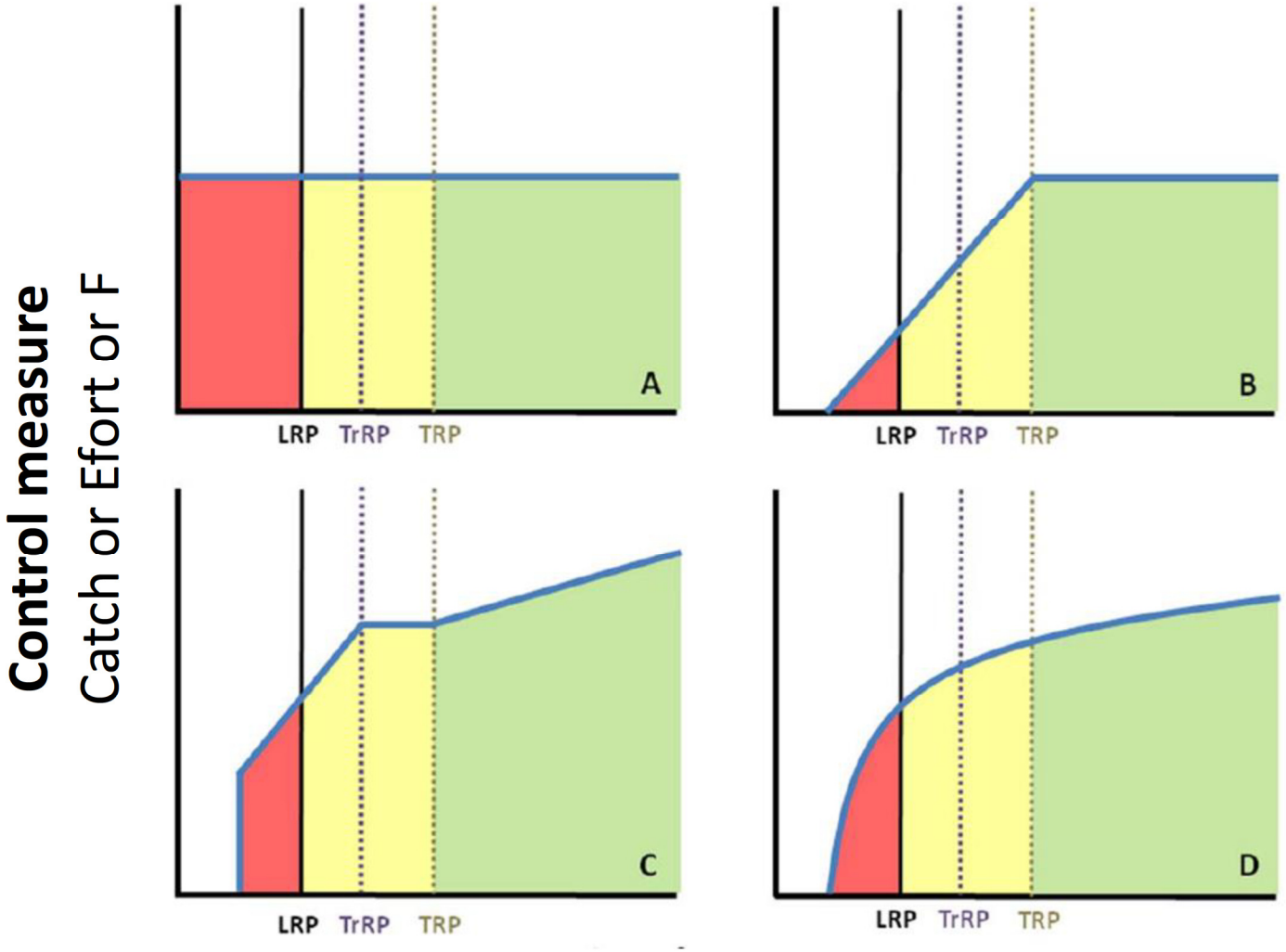
Harvest Control Rule examples



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Modified from Berger et al. 2012

Harvest Strategies

- Combination of monitoring, **stock status evaluation**, harvest control rule (with or without Reference Points) and management actions designed to achieve fisheries objectives.
- Management actions include for example: limited access, allocation of fishing rights, **input and/or output controls**.
- The level of detail and emphasis of harvest strategy elements varies by fisheries and their historical context (e.g. developing, stable, rebuilding) in particular relative to the level of development of monitoring and management systems

Limit Reference Points: considerations

- Reaching LRP should not mean a high risk of biological extinction: appropriate response would be a reduction in fishing mortality rather than the closure of the whole fishery. (Punt and Smith 2001)
- The probability of triggering a LRP should be low, but not zero.
- Stocks are expected to fluctuate around a TRP, and to have a very low probability of triggering a LRP (Sainsbury 2008).
- LRPs have been traditionally set on biological grounds to protect a stock from serious, slowly reversible, or irreversible fishing impacts, which include recruitment overfishing, genetic modification (Sainsbury 2008).
- In practical terms, this generally means determining the effect of exploitation on recruitment, typically through evaluating the stock-recruitment relationship.

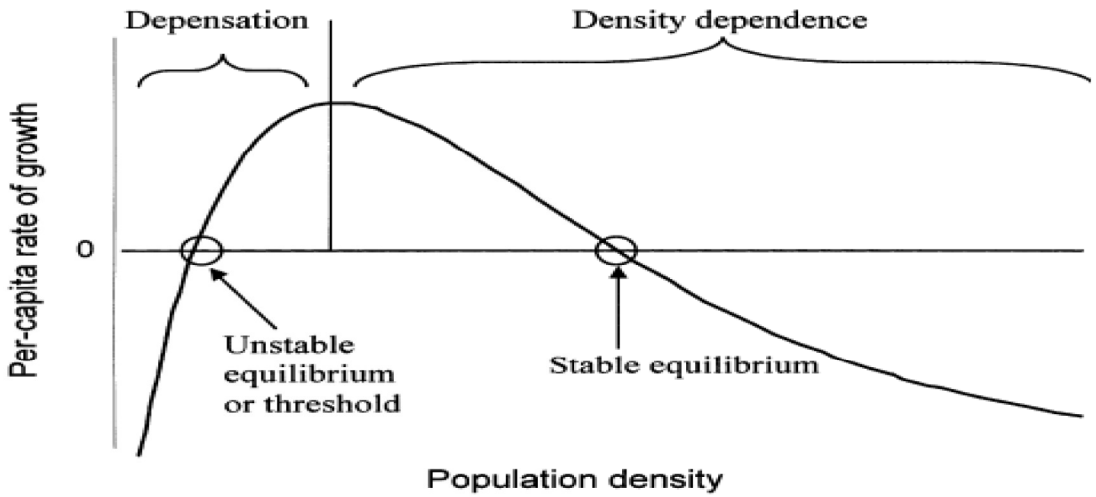
Spawner-Recruit & Recruit-Spawner relationships…or apparent lack thereof

- Which came first: the chicken or the egg
- Low recruitment at low spawner abundance
  - But how low is too low?
- Rate of increase in recruitment slows at higher spawner abundance
  - Population would grow exponentially or decline to extinction otherwise
- Unknown pattern at very high spawner abundance: low recruitment or a high asymptote in recruitment?
- It is possible that recruits bear no (apparent) relation to spawners and are driven by the environment
  - But something has to spawn them…

Dynamics of populations at low abundance

- Concerns about undesirable processes such as impaired recruitment and **depensation** (disproportionally large negative impacts on stocks at low abundance).

  - Random events
  - Predation
  - Difficult to find mates
  - Other (inbreeding, lost group benefits)



From Liermann and Hilborn 2001

- Several studies found little, if any, support for depensation across > 100 stocks, however depensation cannot be ruled out given limited availability of data and research to date.

- *“The real goal of fisheries management is to avoid finding out what the stock-recruitment relationship is. Once you have depleted the stock enough to know, it’s probably too late”*

John Shepherd, 1980

Recently proposed LRP for Pacific bluefin tuna (Nakatsuka et al. 2017)

Pacific Bluefin Tuna

Valero et al. (2017). IATTC SAC-0805e(ii)

Modified from Nakatsuka et al. 2017

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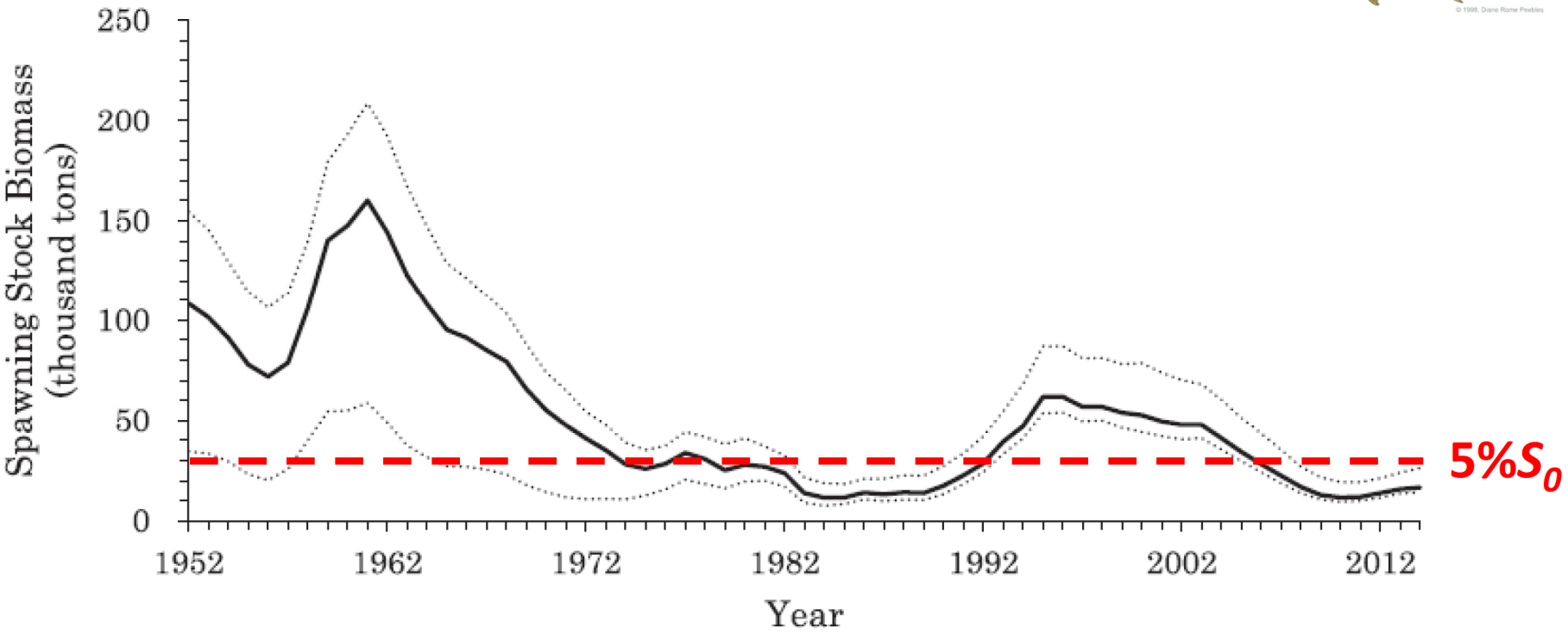
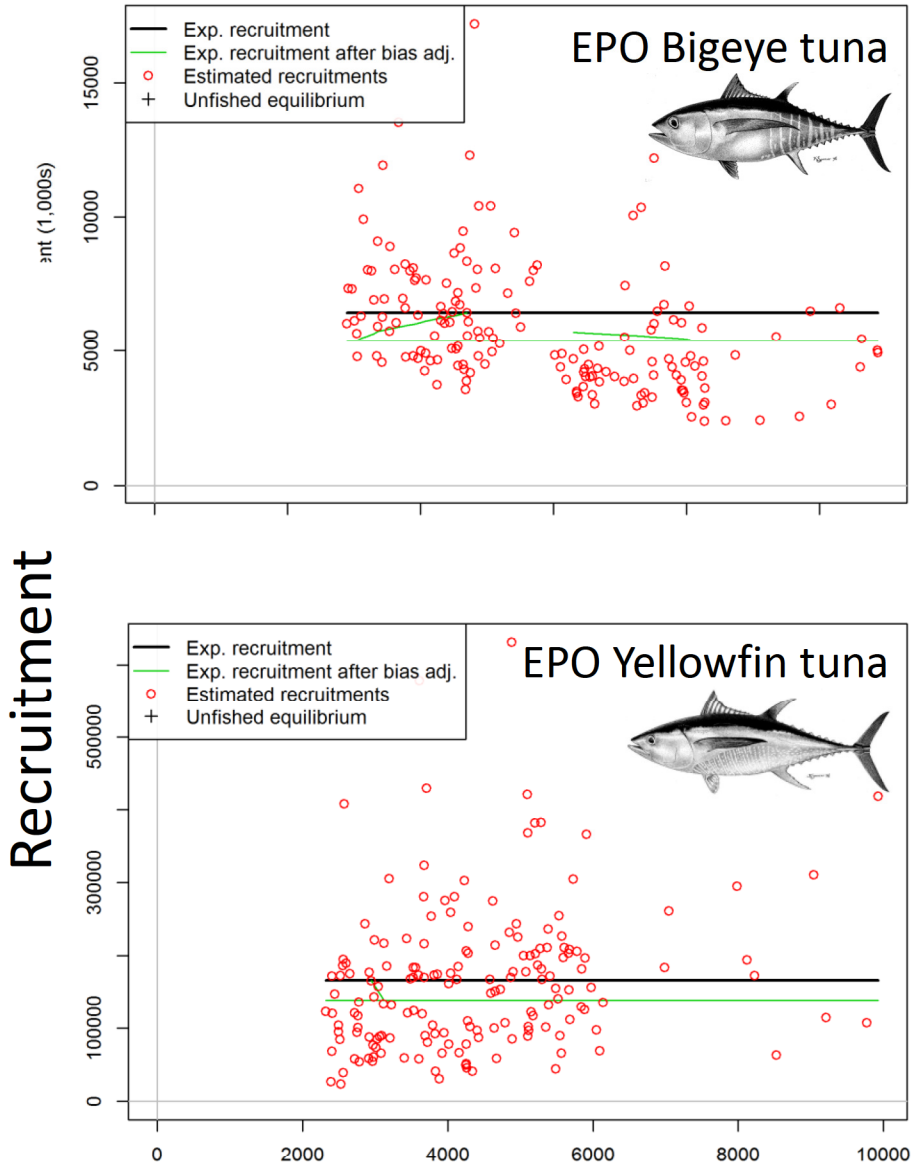


Valero et al. (2017). IATTC SAC-0805e(ii)

Modified from Nakatsuka et al. 2017

RP and HCR for tuna and billfish stocks



- No identifiable Spawner-recruit relationship
- EPO YFT and BET stock assesments by IATTC assume steepness *h*=1

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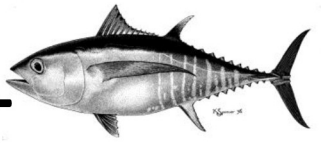
IATTC Limit Reference Point



- IATTC adopted interim target (TRP) and limit (LRP) reference points in 2014.
- Target:
  - Biomass (*B*) and Fishing mortality rate (*F*) corresponding to maximum sustainable yield (B_{MSY} and F_{MSY})
- Limit:
  - Those associated with a 50% reduction in unfished recruitment (50%R_0) using a conservative assumption of stock-recruitment relationship (steepness, or h = 0.75).

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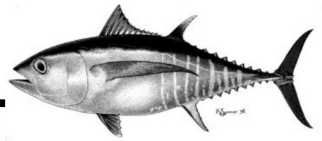
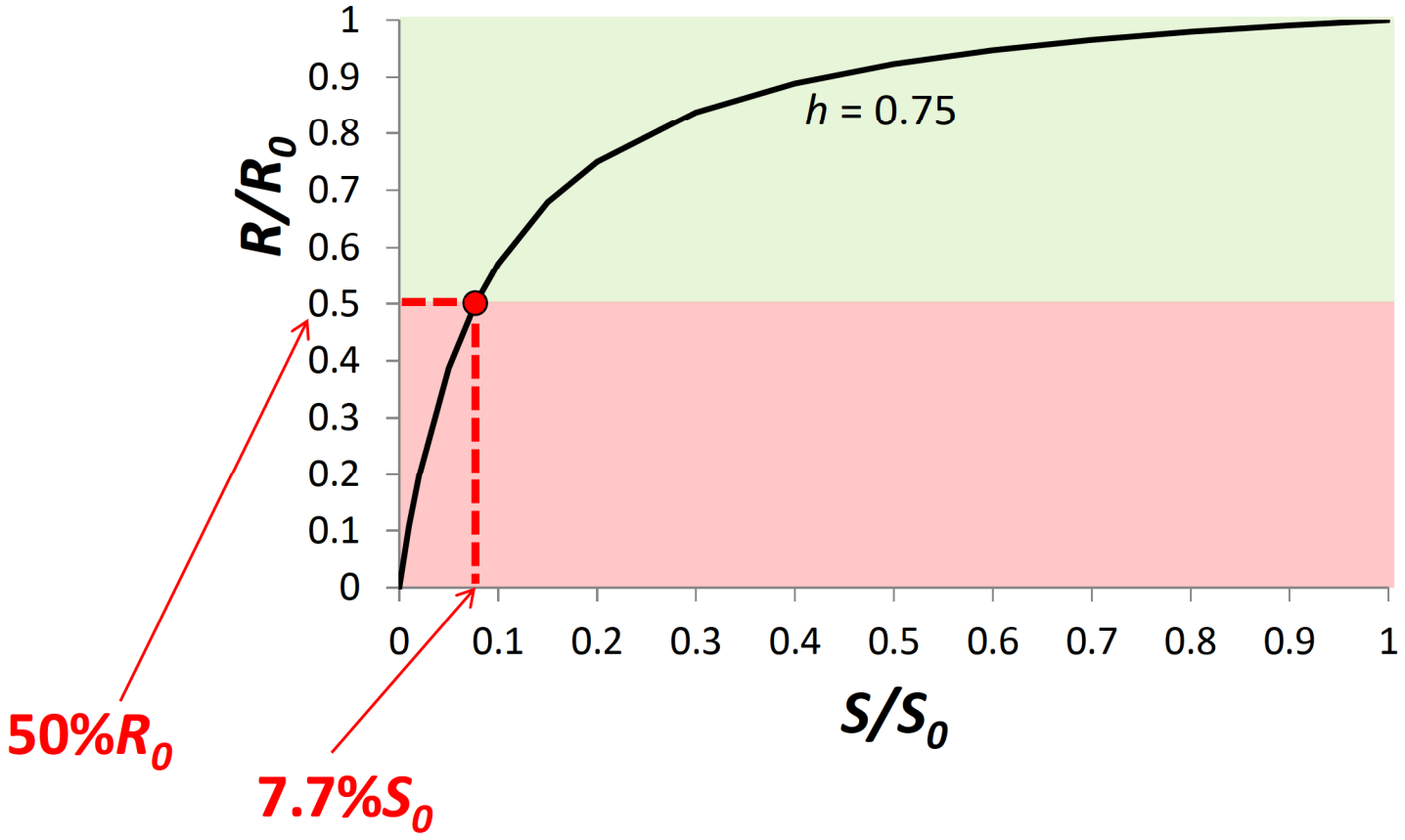
IATTC Limit Reference Point





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Reference points and Harvest Control Rules adopted by tuna RFMOs

RFMO Element	CCSBT	IATTC	ICCAT	IOTC	WCPFC
LRP	None	Tropical tunas: $F_{0.5R0}$ and $B_{0.5R0}$ evaluated assuming a steepness of 0.75. Relates to a depletion of 0.077B0. (interim limits)	N. Atlantic swordfish: 0.4 B_{MSY} (interim limit)	Tropical tunas: 0.4 B_{MSY} (0.5 B_{MSY} for BET) (interim limits)	Tropical tunas and S. Pacific albacore: 0.2 $SB_{F=0}$ (0.2B0) evaluated using recent recruitment levels
TRP	None	B_{MSY} and F_{MSY}	"Green" quadrant of Kobe plot seems a target zone, but no specific TRP adopted.	Tropical tunas, albacore and swordfish: B_{MSY} and F_{MSY}	Skipjack $0.5B_{F=0}$
HCR	Empirical (Juvenile survey, CPUE)	Tropical tunas: Reduce *F* to F_{MSY} if it exceeds this value	None	None	None

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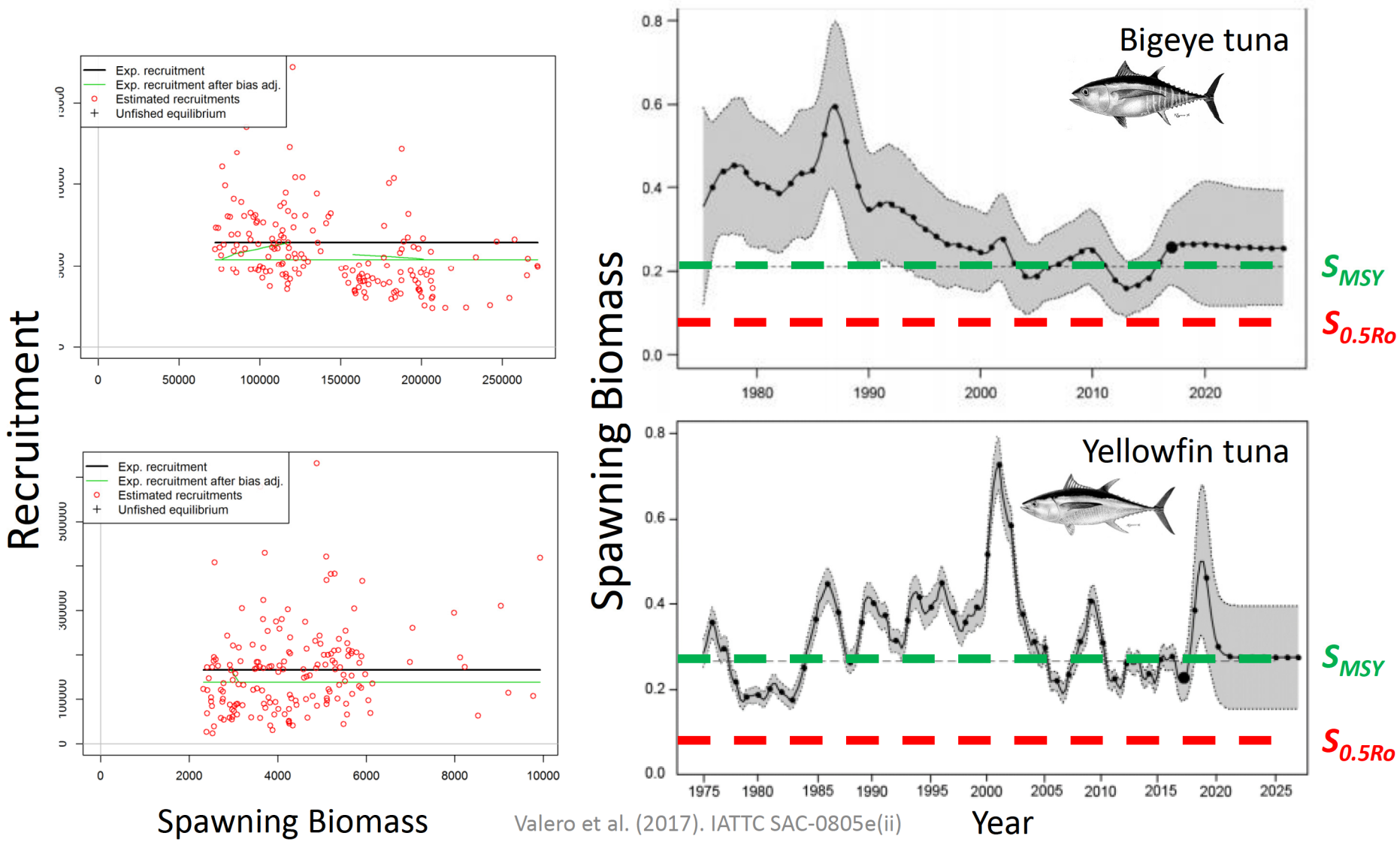
RP and HCR for tuna and billfish stocks



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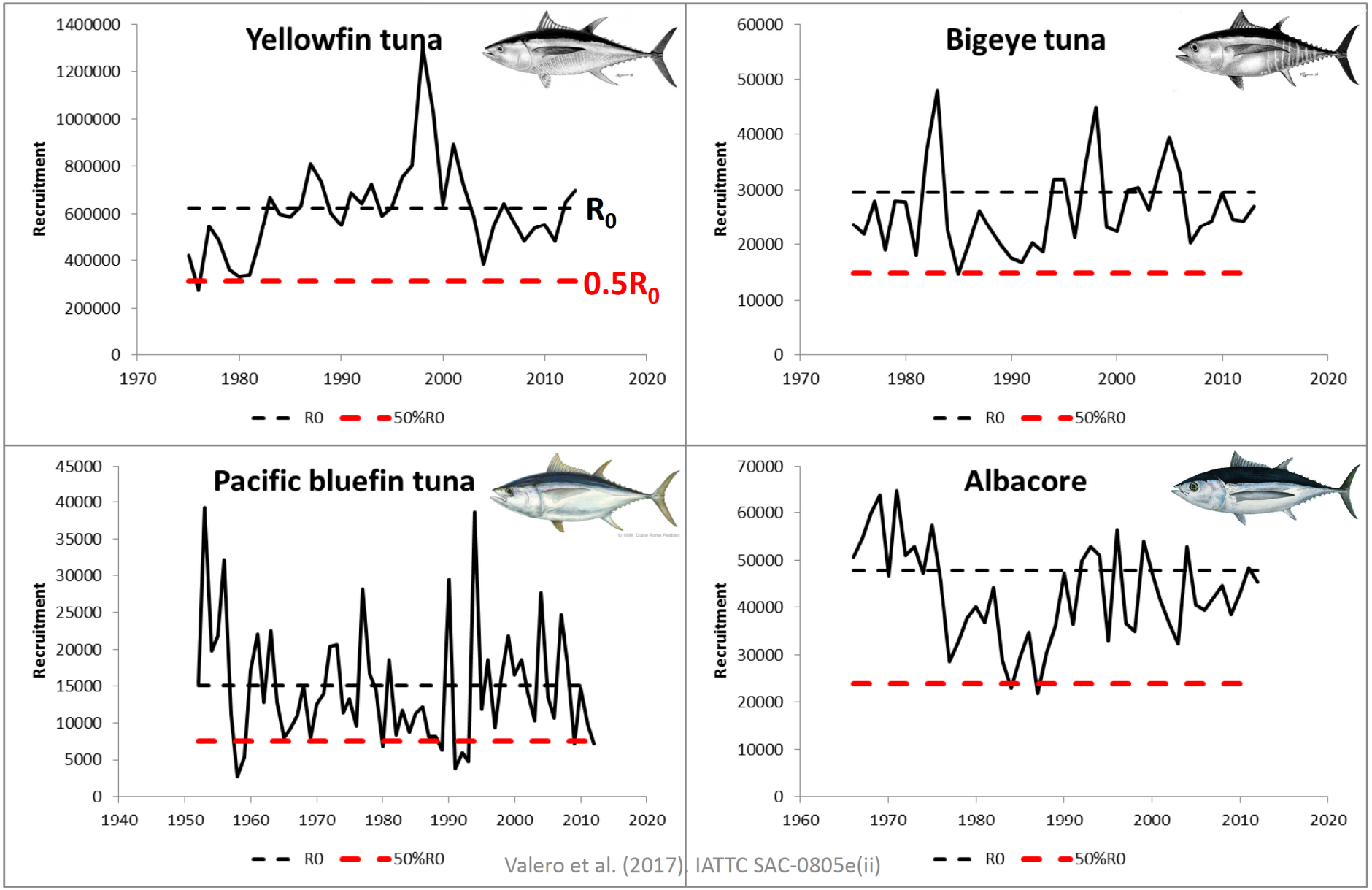

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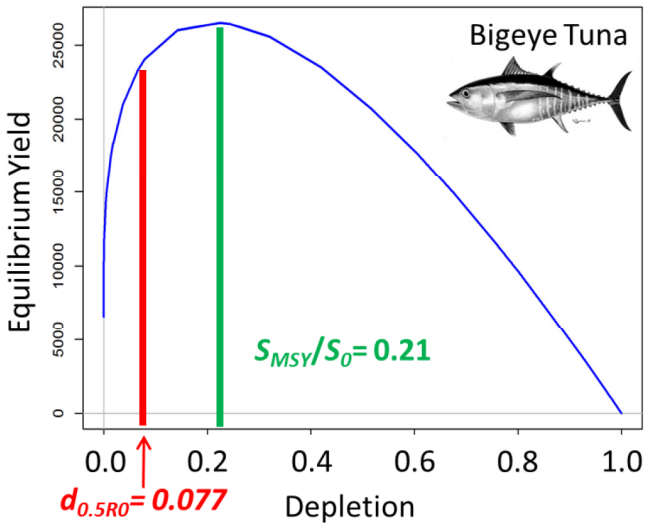

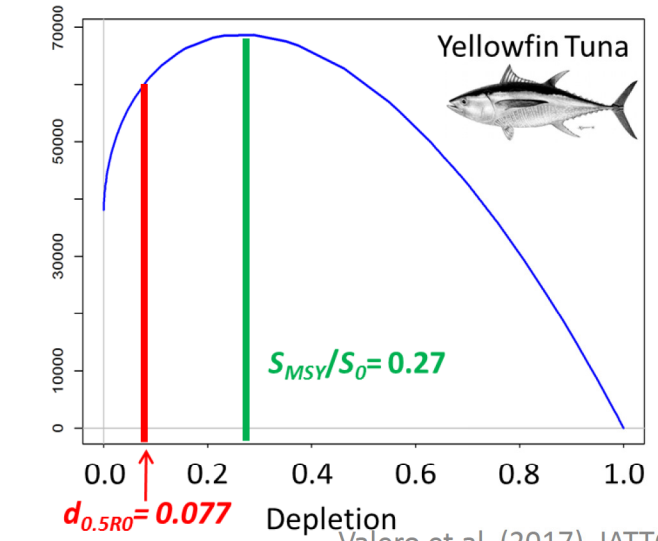

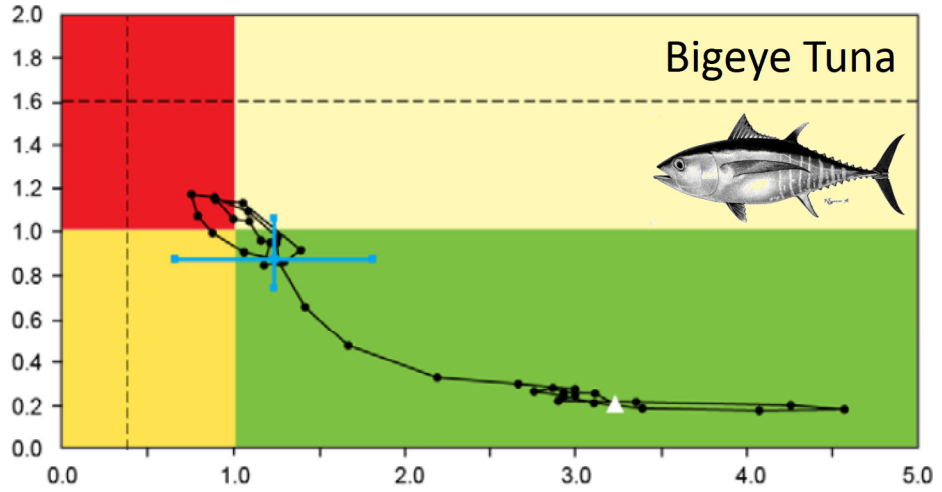

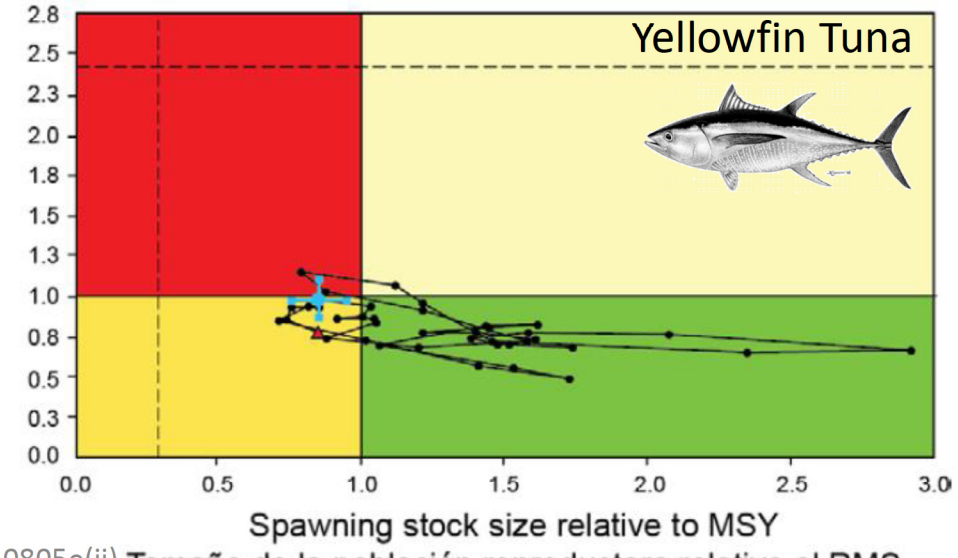

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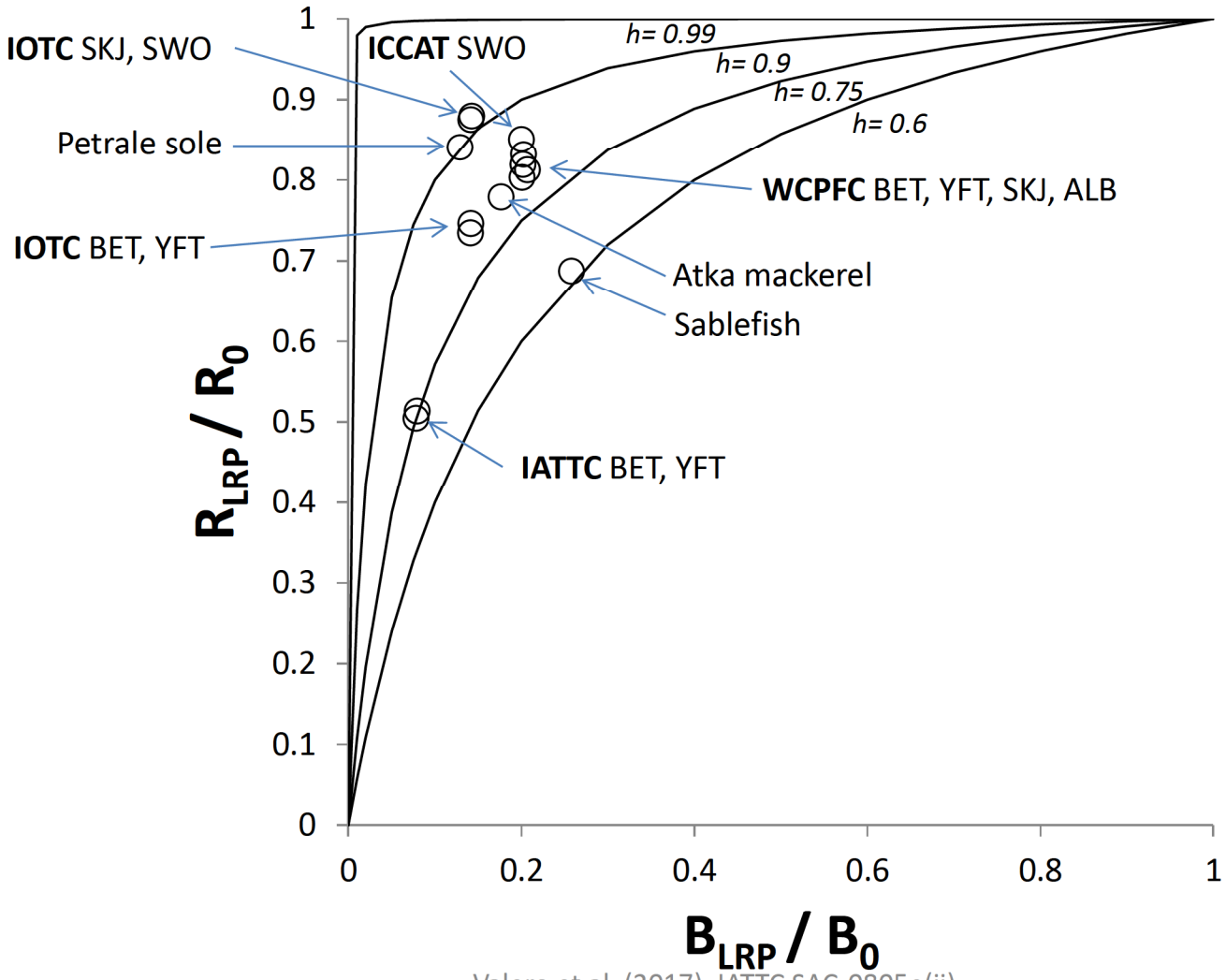
Limit reference points by management bodies, steepness (h) and stocks

	GROUP	STOCK	LRP	LRP/B_0	h	R_{LRP}/R_0
CCSBT	Tuna	SBT	None	N/A	N/A	N/A
IATTC	Tuna	BET	$B_{0.5R0}$	**0.077**	**0.750**	**0.500**
		YFT	$B_{0.5R0}$	**0.077**	**0.750**	**0.500**
ICCAT	Billfish	SWO-N	$0.4\ B_{MSY}$	**0.200**	**0.830**	**0.830**
IOTC	Tuna	BET	$0.5\ B_{MSY}$	**0.140**	**0.800**	**0.723**
		YFT	$0.4\ B_{MSY}$	**0.140**	**0.800**	**0.723**
		SKJ	$0.4\ B_{MSY}$	**0.140**	**0.900**	**0.854**
	Billfish	SWO	$0.4\ B_{MSY}$	**0.140**	**0.900**	**0.854**
WCPFC	Tuna	BET	$0.2\ B_{,F=0}$	**0.200**	**0.800**	**0.800**
		SKJ	$0.2\ B_{,F=0}$	**0.200**	**0.800**	**0.800**
		YFT	$0.2\ B_{,F=0}$	**0.200**	**0.800**	**0.800**
		ALB-S	$0.2\ B_{,F=0}$	**0.200**	**0.800**	**0.800**
NOAA - WC	Grounfish, Tier 1,2	Sablefish	$0.25\ B_0$	**0.250**	**0.600**	**0.667**
	Flatfish	Petrale	$0.125\ B_0$	**0.125**	**0.900**	**0.837**
NOAA - AK	Groundfish, Tier 3	Atka Mackerel	$0.5\ B_{MSY}$	**0.175**	**0.800**	**0.772**
IPHC	Flatfish	Halibut	$0.2\ B_0$	**0.200**		
Australia	Various	Various	$0.5\ B_{MSY}$	**0.200**		
NZ (soft)	Various	Various	$0.5\ B_{MSY}$	**0.200**		
NZ (hard)	Various	Various	$0.25\ B_{MSY}$	**0.100**		
ICES	Medium/Long living	Various	Reduction in recruitment based on SRR	Varies		
NAFO	Various	Various	Various	Varies		

Valero et al. (2017). IATTC SAC-0805e(ii)

Limit reference points by management bodies, steepness (h) and stocks



Valero et al. (2017). IATTC SAC-0805e(ii)

Summary

- Little if any evidence of depensation in literature
- Most stocks recover from low levels after fishing pressure is reduced
- Most LRP are arbitrary
- Potential issues of specifying reference points that may not relate to specific life histories of stocks
- LRP cannot be evaluated in isolation of other elements of strategy (TRP, HCR), harvest strategy
- Which LRPs are appropriate depends on management action to be applied if the limit is exceeded.

Summary: tuna and billfish stocks

- Tuna RFMOs differ in approach, rational and stage of implementation of reference points
- Most of LRP are not necessarily based on biological information on the respective species
- Differences in MSY as a limit or target and level of implementation of harvest control rules.
- IATTC only tuna RFMO with adopted TRP, LRP (since 2014) , HCR (since 2016) for tropical tunas
- Performance of reference points and HCR remains to be evaluated across tuna RFMOs
- Simulation testing work such as MSE can be an effective evaluation approach, ongoing in some RFMOs

Valero et al. (2017). IATTC SAC-0805e(ii)

Thank you!
Questions?

Valero et al. (2017). IATTC SAC-0805e(ii)